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Venture capital in the UK: A regional deal?

By

Stuart James Parris

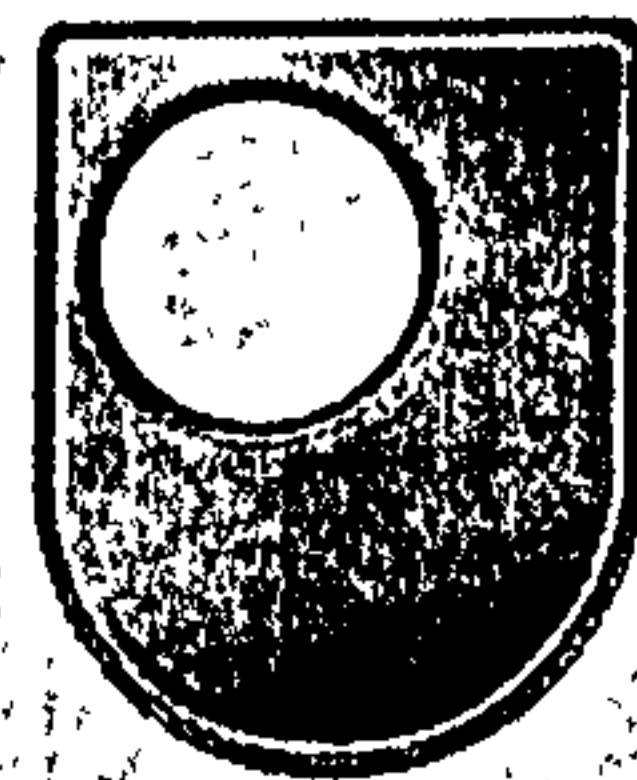
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Abstract

In this thesis we examine the organisation of the UK venture capital industry. We draw on literature from finance, innovation and economic geography in order to build a model to understand the relationship between the distribution of investment and regional resources. Using network theory we then extend this model in order to understand the structure of ties between actors in the venture capital investment process. Thus, we analyse the relationship between regional venture capital activity in the UK and a range of relevant regional resources.

The thesis argues that patterns of investment activity in the UK are well established, with well defined regional concentrations, resulting from the geographically-embedded nature of venture capital. However, at a sector level, regional relationships between local resources and investment vary. We find that investment in biotechnology is less regionally embedded and strongly influenced by changes in local resources, such as R&D.

Although we demonstrate venture capital networks operate at a national level, our network analysis shows that regional variations persist in the strength and quality of relationships between investors and entrepreneurial directors. Consistent with a regionally embedded venture capital industry, and in agreement with social capital theory, our analysis indicates distinctive regional network patterns which support local investment activity.

This thesis supports a regional innovation systems approach where the investor plays an important role in defining the system. However, we emphasise that individual regions may adopt different systems with regards to the presence and operation of venture capital, as a result of the distinctive characteristics of each region, their history, proximity to London and the structure of social networks. We suggest that policy can play a role in supporting these systems if it is sensitive to the variation in regional dynamics and takes account of access to entrepreneurial resources located outside the region.

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During my time at the Open University I have been fortunate to present my work at several conferences, meet with academics from other universities working in similar fields as well as conduct interviews with investors active in financing start-up firms. These experiences have been a huge benefit and helped to improve my thesis. Therefore I would like to acknowledge the help of this group of people.

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1 Introduction

1.1 Aims and motivation

The adequate provision of risk based finance to entrepreneurial firms is critical for the commercial exploitation of innovation, particularly in hi-tech sectors such as biotechnology. However, the availability of venture capital investment is not evenly distributed within nations. In fact, venture capital investment is known to be concentrated in particular locations. It follows that the expertise associated with growing venture capital backed entrepreneurial firms is also concentrated in the same locations. This thesis sets out to find whether these are also features of the venture capital industry in the UK.

The aim of this thesis is to understand the financing of hi-tech commercialisation in the UK. The thesis is organised around the theme of exploring relationships between finance and hi-tech innovation from a regional perspective. A sub-theme of the thesis is to understand these relationships in the context of small to medium sized enterprises that operate in the biotechnology and pharmaceutical sector. Specifically the thesis explores the presence and effects of heterogeneity in the provision of venture capital in the UK through a study of the biopharmaceutical sector, venture capital fund manager's social networks and venture-funded firms' director's affiliations.

1.1.1 Research Questions

Our motivation for this research is centred on producing a comprehensive understanding of the dynamics of venture capital in the UK. We achieve this by using a multi-level analysis which dictates a mixed method approach. We utilise several related academic literatures to narrow our subject of study to a set of key research questions, which are as follows:

1. What are the regional level determinants of venture capital investment in the UK?

Sub question: Are the relationships between biopharmaceutical investment and regional resources different from other sectors?

2. What relationships exist between investors, firms and entrepreneurial firm directors, how are these relationships organised and how does this relate to regional investment?

The research questions are motivated by gaps found in the literature review. These research gaps on UK venture capital include the lack of systematic comparisons of investment activity across regions in time, and weaknesses in the detailed analysis of the regional investment process. Finally, following the emphasis on the use of networks by

US based venture capital; we apply a network perspective to our research on UK investors. The combination of these complementary approaches defines the PhD thesis. In the next section we justify the research focus, outline our thesis argument and detail the structure of the thesis.

1.1.2 Motivations for research questions

Over the last decade many national governments have been keen to develop a strong culture of entrepreneurship, creating policies to encourage entrepreneurial activity. At the core of this motivation has been a desire to develop national economies through the commercial exploitation of national innovation and knowledge. The benefits of this strategy are expected to result in generating employment, wealth and national prosperity.

A core aspect of the national level motivation has been to focus on policy at the regional level. In the 1990's this was formed around the concept of encouraging innovation through high tech clusters. More recently innovation policy has been increasingly viewed from regional perspective and influenced by academic work on regional innovation systems (Boekholt and Jaker, 2004). A common aspect to both regional innovation systems and cluster building approaches is the desire to replicate the success of areas such as Silicon Valley in the USA. Silicon Valley is a very well known example of where public investment in basic research and development, and a culture of entrepreneurial start-ups have been supported by the availability of risk based finance. Silicon Valley is associated with many start-ups that have grown rapidly to become much admired names in world business.

The venture capitalist is a core actor in the process of entrepreneurial firm and regional development. The venture capitalist operates at the interface of innovation and finance. In this role the venture capital firm acts as fundraiser and investor. Fundraising involves the venture capital firm demonstrating the necessary expertise to convince large corporate investors and pension fund managers of their ability to manage investment funds and produce profit. To return a profit, venture capitalists need to acquire and apply the experience necessary to successfully act as a 'gatekeeper' to new innovations. In this gatekeeper role their ability to select investment opportunities and support their development, determines whether they can pick promising ideas to turn into high value businesses.

As such, venture capitalists are seen to be a key intermediary in the life cycle of entrepreneurial firms. It follows that if we can understand how this form of financing operates, we can assist governments in exploiting their hi-tech opportunities. In the US, where the venture capital industry first started, venture capital has evolved to become an important source of finance for new technology based entrepreneurial firms. Now, many countries have access to venture capital from home-grown and foreign venture capitalists.

1.1.3 Investment concentration and regions

Despite the globalisation of venture capital investment, the distribution of investment within nations is concentrated into key locations. These locations are perceived as offering the right resources and balance between demand for capital and supply of investment.

In the UK, the evolution of the venture capital industry has been noted as lacking a focus on entrepreneurial early stage business. UK Governments have been concerned about the lack of risk based finance for entrepreneurial firms since the 1930s. This topic has received considerable attention over recent years, culminating in the creation of regional venture capital funds. The aim of these funds was to create local access to venture capital for entrepreneurs in any UK region. This policy has been criticised for failing to understand the dynamics of the industry. This generates our first research question:

What are the regional level determinants of venture capital investment in the UK?

This thesis contributes an assessment of the dynamics of venture capital at the regional level, by providing a systematic analysis of determinants of regional venture capital investment in the UK. The current view of the role of venture capital is based heavily on literature from the US. As a result, this thesis can also inform the general literature on venture capital, by providing additional detail of practice in the UK.

Another important motivation for this thesis is concerned with understanding the role of finance in the development of biotechnology and pharmaceutical small and medium sized enterprises (SME). It is generally accepted that the biotechnology industry has been slow to produce new products or realise the commercial potential of this technology; a potential which was widely anticipated in the 1970s and 1980s. Despite performance concerns, the sector remains an important long term economic prospect given the advances in genetic technologies in the last decade. These advances are expected to provide new opportunities for the development of healthcare solutions to complex diseases. The complexities of the

sector mean it is of key interest to research aimed at understanding the commercialisation of innovation.

The potential market for solutions to remaining incurable diseases is estimated to be worth as much as \$1.6 trillion (Northrup, 2005). However, for the pharmaceutical industry to capture this market, it is increasingly dependent on biotechnology and pharmaceutical small and medium sized enterprise (SME) to sustain its revenues. SME contribute to the pharmaceutical industry by sourcing new knowledge, innovation and products, which are often sold to large multi-national pharmaceutical firms. For these reasons, the development of SME's in the biotechnology and pharmaceutical sector is important for the development of new healthcare solutions and for the national economy. In 1999 the UK Governments Biotechnology Cluster report, led by Lord Sainsbury, reported that the biotechnology industry and associated services accounted for 40,000 UK jobs. Thus, understanding more about the demands of this sector is of key policy interest.

A crucial need for SME biopharmaceutical firms is finance. The development costs for firms in this sector are massive, due to the capital intensive nature of R&D, the regulatory burden and ultimately the lengthy timescales even to proof-of-concept stages. This means that biopharmaceutical SMEs demand large amounts of finance at a level of risk that generally prohibits traditional forms of start-up funding, such as bank loans. Venture capitalists that are prepared to live with these strong financial demands, accept the higher risks with the expectation of large potential returns. For biotechnology firms to offer large returns they must show how their potential products and services will address the demands of large international markets.

Venture capitalists are expected to play a key role in financing and developing SME firms. In particular they are expected to support new radical innovations such as biotechnology, where other investors would disapprove of the risk. On a regional basis, we investigate what factors are important in deciding the regional level of biopharmaceutical investment received, and how this compares to other sectors. This gives our sub-question:

Are the relationships between biopharmaceutical investment and regional resources different from other sectors?

1.1.4 Venture capitalists and relationships

Venture capitalists are central agents in the financing of innovative technology for commercial purposes. Venture capitalists provide the finance necessary for the development and growth of SME firms. In the process of maximising their investment return they also contribute to the governance and direction of the firm.

The importance of venture capitalists, and other types of actors who support innovative firms at a regional level, is a feature of literature on regional innovation systems. In this literature there is particular emphasis on key individuals and their relationships which help regional development. Thus, we also argue that venture capitalists fulfil an important role in the process of regional development, acting as key networking agents between entrepreneurial firms and other sources of finance. As the network coordinators, venture capitalists, through their investment activities, also become intermediaries for the transfer of information, knowledge and expertise. In addition they help in the recruitment of other specialist expertise, which has regional level benefits. We argue that networks are crucial to the successful operation of venture capital and symbiotically the development of regions.

In the UK little research has been focused on understanding the presence and role of key actors in biopharmaceutical SME regional innovation systems. A predominantly US literature maintains that investors do not operate in isolation. The identification of key UK actors and the relationships with other actors is less well understood. Therefore in line with the main relational theme of the thesis, we look at relationships: between investors; between investors and firms; and between directors of firms in the biopharmaceutical sector. This gives our final research question:

What relationships exist between investors, firms and entrepreneurial firm directors, how are these relationships organised and how does this relate to regional investment activity?

In summary, our research questions are concerned with relationships. Firstly, in terms of investment levels we look at the relationship between finance and regional resources. Then secondly in terms of the investment process, we examine the relationships created by venture capitalist whilst pursuing their own interests.

In answering the thesis questions we examine two regional perspectives of the organisation of the venture capital industry in the UK. Firstly, we explain the factors affecting investment concentration across regions. Secondly we analyse the detailed patterns of

interaction formed by investors. Combining these two perspectives provide a comprehensive understanding of the dynamics of venture capital in the UK.

In summary, we support our research aims by examining the dynamics of the UK venture capital industry. We evaluate the general state of the UK venture capital industry, at the early and later investment stages, and across different technology sectors. We also evaluate the political aspects of venture capital, through an assessment of the impacts of public finance. Finally, we consider the industry as structured by relationships between investors and supporting entrepreneurial actors. The result is an assessment of UK venture capital which is sensitive to regional variation in the relationships between investment, resources and the actors that make investments happen.

1.2 Argument

We find that UK venture capital, despite being dwarfed by the private equity and buy out industry, is well developed. Investor participation, in terms of syndicate size, is on par with that of other countries. We also find that, like other developed nations, venture capital naturally concentrates into a minority of regions. We find that these concentrations are persistent over time; regional investment activity changes very slowly.

However, there are sector differences. For biopharmaceutical firms, we find large pools of fund managers¹ (i.e. the investors of venture capital funds, rather than limited partners who invest into venture capital funds) willing to provide finance, although in smaller amounts than in countries such as the US. The distribution of biopharmaceutical investment is more strongly linked to changes of regional resources, such as R&D, whereas in non-biopharmaceutical sectors and the industry in general, we find more distinctive regional effects which are persistent overtime.

Throughout the analysis we view the UK as constructed from heterogeneous regions, where investment activity can be linked to the regional resources and characteristics of that particular region and its relationships to others. UK VC funding is concentrated into the East, South East and London. London is a massive financial centre and home of virtually all large investors; as a result London is at the centre of UK investment activity. Proximity to London has a large influence on investment activity. In contrast to regions such as Silicon Valley, a hi-tech region with strong local ties between fund managers, venture

¹ Throughout this thesis the use of terms such as investor refer to fund managers, rather than limited partners who invest into venture capital funds.

capitalists in the UK are closely tied to the nation's major financial hub. In the UK, despite the large numbers of investors and a general willingness to participate in the financing of SME, only a minority of investors are central to the operation of the VC industry. Likewise, an even smaller minority of investors are central to biopharmaceuticals. We also find little evidence of large established investors who operate on a localised basis. Instead, we find well networked established investors who operate on a national basis, with multiple office locations dominating venture capital activity in the UK. Without doubt, London dominates the venture capital industry in the UK and acts as the national base.

In biopharmaceutical investment we also find the major national players provide coverage of the UK, suggesting that distance does not necessarily prevent access to capital. We find London's investors play a supporting role in places like Cambridge. Resources from London, such as investment and spin out firms, help to support Eastern regions activities, but biopharmaceutical investment and expertise in managing biopharmaceutical firms is concentrated around Cambridge. In places like Scotland, which has also attracted investment in biopharmaceuticals, we find a diverse range of supporting actors, including investors from London and experienced directors from Cambridge.

Although our analysis of the national investment networks indicates a UK-wide network, organised around investors rather than places, a detailed analysis indicates distinctive social structures that relate to specific locations. For example, we find an absence of strong trust based relationships between investors and directors in regions such as Scotland and Yorkshire, as shown by a lack of repeated syndicates and repeated relationships between firm directors. The lack of strong relations is expected to restrict the ability of actors within these regions to share information and cumulatively develop expertise. In agreement with the theory of social capital, places such as the East are associated with strong networks and established groups of investors and directors. This finding is evidence for the valuable regional contribution of relationships, beyond the contribution made by individuals.

In agreement with network theories such as 'small world' and hub type systems, we find the link between our national and regional views of venture capital activity. In these network theories the role of a minority of highly linked actors, provide ties that operate across the UK. However, we find differences in the network structures of investors and directors.

We find that even investors with a strong local presence, such as a local office, also tend to have interests outside of the region. Our findings suggest that VC in the UK is about developing national players rather than regional investors. Ensuring the presence of a regional VC maybe a valid strategy for providing access to entrepreneurial skills and experience, but artificial constraints on investment geography are a weakness (both for the VC firm and more generally for the future development of the region). Geographical constraints work against policy expectations that Regional Venture Capital Funds (RVCF) will eventually become established investors. For example investors with strong ties to the Cambridge region also provide investment to firms in Scotland. We conclude that policy attempts to restrict investment to particular locations are likely to fail.

Investment may travel, but people and expertise do not. Despite a large number of investment firms, (public, public-private and a range of private players) the industry is reliant on a relatively small core of investment executives and a small core of directors with experience of managing investments who work across multiple boards. Firm directors with ties to national investors have a strong presence on SME company boards and affiliations to multiple firms. Examining the level of support provided to the firm demonstrates the majority of directors with multiple affiliations tend to remain tied to a particular location. In contrast, venture capitalists are the main business agents that operate across biopharmaceutical firms in multiple locations.

We argue that this thesis supports a regional innovation systems approach, that the investor plays an important role in defining regional innovation activity. However, we emphasise that systems are sensitive to the distinctive characteristics of each region, their history, proximity to London and the structure of social networks which are influenced by a variety of factors. Investors use extensive nationally organised investment networks to obtain information about opportunities and create syndicates to finance distant firms. However, our regional analysis suggests distinctive patterns of regional activity, concentration in expertise and finance, and variances in syndicate sizes. We also find that regional relationships between local resources and investment vary according to sector. We suggest that regional policy can play a role in supporting these systems if it is sensitive to the variation in regional dynamics.

1.3 Thesis structure

The remainder of the thesis is structured as follows:

In Chapter 2, we lay the ground work for the thesis by reviewing the relevant literature. We take perspectives from literature on venture capital, entrepreneurship and regional development to build an understanding of how the financing of hi-tech firms operates. Firstly, we look at a national level across literature on different countries, mainly the UK and US. Then we look at how investment activity varies within nations. We extend this review to concentrate on the biotechnology sector, a particularly demanding area of technology innovation.

In Chapter 2 we develop our focus for the thesis. We position this research between theories of financing innovation; specifically that the venture capitalist role is as an accelerant in the development of innovative firms, in conjunction with theory on regional innovation systems, which act to support these innovative firms. In combining these perspectives, we can understand venture capital as an important regional actor in supporting innovative firms.

In Chapter 3 we address the issue of networking in venture capital. We show that networking is considered to be an important activity in venture capital and particularly relevant to entrepreneurial firms. In this chapter we build on the literature review in Chapter 2. We review the variety of network analysis perspectives and construct a framework for the analysis of networks in the remainder of the thesis.

Chapter 4 introduces the approach used in the PhD and justifies the methods used in each part of the empirical work. We also describe the organisation of the PhD and deal with ethical considerations. This chapter helps explain the evolutionary organisation of the thesis, moving from an analysis of the organisation of the UK venture capital industry to the specifics of how these activities are co-ordinated in different UK regions.

In Chapter 5 we present and analyse an econometric model of factors driving the distribution of regional investment activity across UK. The analysis uses investment data on the private equity industry. In Chapter 6 we repeat this analysis with a new database on SME investment detailing activity of different industry sectors. In this chapter we compare the regional investment in biotechnology to that of the other sectors.

We use Chapters 5 and 6 to demonstrate that investment in the UK is concentrated into particular locations. In these chapters we also explore a set of expectations generated from the literature regarding the factors that determine the organisation of venture capital in the

UK. We show that our understanding of the organisation of venture capital is dependent on our knowledge of networks, providing an additional incentive to research the organisation of venture capital networks in Chapter 7 and 8.

In Chapter 7 we continue our analysis of UK venture capital investors by analysing the networks created from the syndication of these investors. Chapter 7 starts the analysis of the network framework described in Chapter 3, analysing the regional social networks present in biotechnology firms receiving venture capital finance.

In chapter 8 we continue our analysis of investment activity on the extent and nature of investment syndication. In this chapter we examine the factors that drive investors to syndicate using regression analysis. Chapter 8 is important because we also consider the motivations of investors to participate in investing in firms. This chapter brings together the regional analysis in Chapters 5 and 6, and the network analysis in Chapter 7. This chapter provides an insight into how the characteristic of firms, locations, deals and investors, determines the participation of investors. It is also an analysis of the building blocks upon which our networks in Chapter 7 are based.

In Chapter 9 we perform a social network analysis of the networks created by the directors of venture capital funded biotechnology firms. From Chapters 7, 8 and 9 we can understand how venture capital functions as a networked activity. We can see how relationships are organised, focusing on those actors that co-ordinate activities. These actors are an important group with the combination of experience, expertise and social connections that partly account for the concentration of activity we observe in the earlier chapters of the thesis.

In Chapter 10 we take stock of our empirical work. We revisit four regions of the UK to examine the detail of relationships between actors in the networks found in Chapters seven and eight to clarify the assumptions we make in earlier chapters. In this chapter we can evaluate the role of venture capitalists active in four UK regions, using additional data provided from interviews, press reports and the Internet.

In the final chapter we summarise the findings from each chapter, discuss the overall conclusions to the thesis questions and conclude with some policy recommendations.

2 Evolution of venture capital and its regional concentration

2.1 Introduction

The purpose of this chapter is to justify the focus of our empirical work and show how we arrive at our research questions. This chapter provides the necessary background on the venture capital industry, regional innovation systems and biotechnology, to appreciate the context in which early stage venture capitalists operate. From these targeted reviews of the literature we demonstrate how the gaps in the current research have influenced the chosen research questions.

The provision of risk capital funding for start-up business is considered an important requirement for developing and supporting entrepreneurial firms. The expected role of the venture capitalist goes beyond the provision of funding in the US, where VC provide both financial and business support to entrepreneurial firms, particularly those in new technology-based markets.

The development of modern forms of venture capital investment and its evolution away from the United States has been well documented. Whilst we have noted that venture capitalists operate in many countries across the world, the UK is seen to have one of the largest venture capital industries after the US. During recent decades, the availability of this form of financing has grown rapidly, driven by the demand for equity based finance from entrepreneurial businesses in regions with a strong technology focus, such as Silicon Valley or Cambridge (UK). The supply of venture capital investment has been encouraged as a means of supporting the development of new entrepreneurial ventures, but when applied to a particular location is shaped by different national and regional forces (Dossani and Kenney, 2002).

In this chapter we first discuss the operation of venture capital and its evolution in the UK. Next we examine the role of venture capital in supporting the biotechnology industry. Then we examine the spatial concentration of venture capital in the US and the UK before finishing this chapter by reflecting on the literature associated with industrial clusters and regional innovation systems.

2.1.1 The model of venture capital operation

Venture capital is a form of finance specifically aimed at growing businesses by providing financial investment and additional business support services. Only certain business opportunities are suitable for venture capital investment. Typically businesses which obtain

funding from venture capitalists are expected to grow rapidly and have the potential to provide significant return on investment. However, the venture capital cycle is very risky. On average only two out of ten investments will meet the original expectations of the venture capitalist and many investments make a loss (Bygrave and Timmons, 1992).

A basic model for operating a venture capital company is largely accepted in the literature. Its historical development, processes and examples of successes and failures, have been provided by Florida and Kenney (1988), Sahlman (1990), Bygrave and Timmons (1992). More recently Gompers and Lerner (2001) have provided a detailed review of the “Venture Capital cycle”. All these studies pertain to the evolution of this model in the United States.

The focus of venture capitalist activities are in the initial 7-10 years of the technology cycle, which starts with the inception of the company and plots its development through the stages of emergence and consolidation. The venture capital cycle starts with a phase of due diligence to assess the investment opportunity. If a decision to invest is made, finance is provided to the company in return for partial ownership and control. The venture capitalist usually takes equity in the company and often reserves the various controlling rights including a position on the firm’s board of directors. Venture capitalists realise the growth in the value of their investment by exiting through public stock markets via initial public offerings (IPO), or through the sale of their equity to another company, known as a trade sale.

Usually, a venture capital investment is followed by an intensive effort by the entrepreneurial team and investors to accelerate development of the company through the technology cycle. In addition to providing finance, the venture capitalist is also expected to take an active involvement in managing firms. This can include providing guidance and assistance on business strategy, access to various business and technology networks, and if necessary recruiting the necessary senior management to develop the firm (Florida and Kenney, 1988). Over the lifetime of an investment, the role of the venture capitalist moves from entrepreneurial support, to more traditional management and marketing inputs, associated with established companies.

For the economy and industry as a whole, venture capital thus assumes an intermediary function between financiers and industry that utilises “overlapping networks” for raising finance, performing due diligence and maintaining the internal resources of the venture capital company itself. Florida and Kenney (1988) suggest that the role of the venture

capitalist is to accelerate the speed of technology change, whilst taking on a “technological gate keeping role” (p.125).

2.1.2 The need for VC finance

The origins of a need for alternative sources of finance from the traditional banking system have been traced back to the early 20th century. Around the 1930s, political and business leaders in both the US and UK, began to discuss the role of investment and expertise for supporting entrepreneurs and small firms, in order to stimulate economic development (Hsu and Kenney, 2005; Campbell, 2003).

In 1931 a UK parliamentary committee chaired by Lord Macmillan identified the fact that compared to other countries the national banking system restricted loans available to new risky start-up enterprises (Campbell, 2003). This perceived gap was later termed the ‘Macmillan gap’ and is now generally referred to as the equity gap. However, the Macmillan gap was not addressed until 1945 when the Bank of England with other major clearing banks established the Industrial and Commercial Finance Corporation (ICPC). ICPC eventually became 3i (Investors in Industry) a major provider of equity investment in the UK (Campbell, 2003)

In 1946 American Research and Development (ARD) was created and demonstrated the potential of a venture capital industry in the US. ARD, a result of the trial of several different organisational forms, aimed to provide investment to small US businesses. ARD’s unique strategy combined raising funds from public and private sources, identifying and selecting suitable investment opportunities, and importantly providing professional management advice. As such, its mission combined being a profitable business as well as delivering wide economic benefits. It also set the practice for the creation of a new generation of investment firms, now known as venture capitalists (Hsu and Kenney, 2005).

Following a number of changes by US Federal Government, the US venture capital industry proliferated. Changes to the tax system, the creation of limited partnerships and other federal initiatives, including the ‘prudent man’ ruling that allowed pension fund managers to invest in venture capital funds, helped to make raising venture capital funds easier. This encouraged the entry of a host of smaller investment firms, which ultimately replaced ARD (Gompers and Lerner, 1999, 2001; Hsu and Kenney, 2005). However

ARD demonstrated the potential of the industry which is now a feature of investment activity in many other countries across the world (Hsu and Kenney, 2005).

2.1.3 Types of venture capital

Bygrave and Timmons (1992) distinguish between 'classic' and 'merchant' private venture capital. 'Classic' venture capital is based on "equity, invested for the longer term" where venture capitalists are, "prepared to live with losers and negative cash flows in the short term" (p.21). 'Classic' type venture capital is important for the financial support of early stage firms, particularly those developing innovative technology which require time and money to reach the market. Venture capitalists are able to provide risk capital because they specialise in managing the high risks applications with potential exists to obtain large returns.

In contrast Bygrave and Timmons (1992) note many countries including the UK have developed a bias towards 'merchant' venture capital. Merchant type venture capital involves investing in established later stage companies, looking for quicker returns at lower risk. Merchant VC deals are often structured as management buy-outs, buy-ins or financing for business expansion, using a combination of equity, debt and more complex financial instruments. 'Merchant' venture capital involves a different skill base, designing complex deals, rather than entrepreneurial skills required for company building in 'classic' venture capital.

Classic type VCs develop a range of capabilities for managing the risks of supporting start-up firms. Firstly they are able to minimise the risks of investing. For example they utilise a range of tools to reduce information gaps and asymmetries between entrepreneurs and investor (Gompers and Lerner, 2001). These tools include close scrutiny of the firm and founders prior to, and during investment; the use of various networks associated with other investors, business people and technology experts to provide information on backgrounds of the founders, the technology and potential market for new technology (Bygrave, 1987; Zook, 2002); using positions on the firms' board to obtain more information on the performance of the firm and actively guide the strategic direction of the firm (Gompers and Lerner, 2001).

Secondly, in addition to providing finance, venture capitalists may actively help the development of the firm. They develop specialist expertise and knowledge as well as a network of contacts to support the development of entrepreneurial firms. For example they

can improve the strategy of the firm by providing advice or recruiting experienced directors to support important decisions (Hellmann and Puri, 2002; Zook, 2004). These ‘value adding’ activities help their investment grow in value, and reduce the probability of failure.

2.1.4 UK Venture Capital

The globalisation of venture capital has shown particular variation with regards to preferences of investment stages (Bygrave and Timmons, 1992; Murray, 1999; Gompers and Lerner, 2001; Mason and Harrison, 2002, 2003). Despite the similarities in the timing of initiatives aimed at supplying risk capital in the US and UK; Bygrave and Timmons (1992), Murray (1999), Gompers and Lerner (2001) and Mason and Harrison (2002, 2003) all state that venture capital investment in the UK has focused on later stage investment opportunities and failed to develop a core of ‘classic’ venture capital skills. The UK is considered to have a relatively low proportion of finance directed towards early stage investing (Bygrave and Timmons, 1992; Gompers and Lerner, 2001).

Despite the creation in 1945 of the precursor to 3i, the UK venture capital industry did not gain momentum until the 1980s (Martin, 1989). Initial investor cohorts were captive organisations, effectively operating as subsidiaries or divisions of larger financial institutions. The VC industry grew through funding available from sources such as insurance firms and pension funds, which enabled the growth of independent venture capital firms (Martin, 1989). However, despite this growth in investment activity, 3i remained the major investor across a range of asset classes (from seed stages upwards) accounting for 33% of the total investment in 1987 (Martin, 1989).

2.1.4.1 *Early stage finance dynamics*

Theoretically, successful early stage investors should have higher rates of return than safer later stage investment funds (Manigart et al, 2002). A higher rate of return should reward investors for the high level of risk and help attract new entrant investors. In reality UK early stage investment has been outperformed by later stage investments (Murray, 1999; BVCA, 2006²). By the late 1980s UK venture capital industry’s activities were concentrated around London; biased towards low frequency but high value management buyout deals (MBO) (Martin, 1989). The strong performance of MBO funds are attributed to the continued emphasis on later stage investing in the UK, and a continued growth in MBO fund size.

² For UK funds created since 1996

One reason offered for the poor performance of UK investors relates to timing. For example, when investor sentiment in the UK has been favourable towards early stage investment, as in the mid 1980s and during the Internet bubble (1999-2000), this has been followed by the collapse of investment values, resulting in finance being diverted to the rapidly growing and more profitable management buy-out market (Murray, 1999. Lockett et al, 2002). In the US, despite the collapse of the Internet bubble, the preference of early stage venture capital over MBO remained (Mason and Harrison, 2002).

In the UK, new entrant investors are critical for maintaining the availability of early stage investment, as incumbent investors tend to migrate towards larger late stage investments. Successful incumbents are able to raise larger fund sizes. Thus in contrast to prediction from theory based on risk and return (Manigart et al, 2002), successful incumbents tend to naturally migrate towards later stage opportunities because it is more efficient to invest in larger deals. This is known in the UK as the “catch 22” (Murray, 1999), or the “double paradox” in the US (Etzkowitz, 2005). For example, 3i, following its public flotation in 1994, has re-positioned the company as a development capital firm, preferring to do deals of at least £1m in size (Sunley, Klagge, Berndt and Martin, 2005). Most recently, 3i and a number of other international investors have confirmed their complete shift from all early stage investment in the UK (Fortson, 2008).

Thus, attracting high quality new entrants can help maintain the supply of early stage investment and fill the investment ‘spaces’ left behind by the evolution of incumbent investors. However, the poor performance of UK early stage funds is unlikely to attract new entrants to fill the gaps left by the migrating incumbents. When early stage investment performance is poor, this naturally motivates incumbent investors to move towards later stage opportunities, and acts as a deterrent to new early stage entrants.

Similarly, early stage investors must raise funds by obtaining suitable backers. This may be difficult in the UK contributors to investment funds may also have a preference for lower risk investments. For example Mayer et al (2005) found that a high level of pension fund contributions to venture capital funds increases later stage, lower risk deals. They found that UK VC funds receive significant backing from pension funds. However, the authors also note that this view differs from Gompers and Lerner (1999) who credits the growth of US Venture Capital on the “prudent man” ruling that allowed pension funds to invest into venture capital funds.

It is likely that a combination of these historical factors have resulted in a low level of private investment aimed at early stage firms. The lack of 'classic' type skills in the UK may also compound the performance of early stage investments. Likewise the poor historical performance of early stage investment has resulted in a small pool of the necessary 'classic' type competences for early stage investment in technology firms. It follows that other investment areas and career options may be perceived as more attractive than working with early stage firms. We can extend this argument to other shareholders in entrepreneurial process, such as serial entrepreneurs and executive directors who might provide expertise to entrepreneurial firms. These actors may forgo a salaried income in return for equity and future returns from working with an early stage firm. Due to the historical poor performance of early stage venture capital backed firms we might expect a relatively small pool of expertise in the UK associated with early stage investing.

2.1.5 Summary

We see that venture capital in the UK has developed differently from that in the US. The US industry has grown rapidly, maintaining an availability of early stage investment. In the UK, since 1931, various Government reports have consistently re-identified issues with access to early stage finance, without being able to successfully apply the resulting recommendations (Oakey and Muhktar, 1999; Oakey, 2003a). This may have consequences for entrepreneurial firms in the UK, particularly those unable to obtain other forms of finance because of their perceived risk, like biotechnology firms.

2.2 *Biotechnology*

In this section we review the literature on biotechnology firms and entrepreneurship. Biotechnology firms play an important role in the development of new innovations in biopharmaceuticals. Biotechnology firms are strongly dependent on venture capitalists to support their initial stages of growth; they are also known to cluster in specific locations offering a supporting environment for innovative start-up firms. We briefly discuss what biotechnology involves, before concentrating on the commercial development of modern biotechnology firms, their relationship with venture capital, and specific geographical locations.

2.2.1 The origins of modern biotechnology

Biotechnology has a diverse range of applications, particularly within the human health/pharmaceutical sector. There are a several different definitions of biotechnology in

use. The DTI³ (Sainsbury, 1999) defines biotechnology as an enabling technology, involving “the application of biological knowledge about living organisms and their components to industrial products and processes”. This can be regarded as a very general definition, as it includes processing applications in the food and agriculture industry. For example, we could argue that the production of yeast for beer and bread making is biotechnology. However, in this review we focus on the activities relating to the commercialisation of biotechnology in the human health biopharmaceutical sector, as it has been described as having the most entrepreneurial firm activity (Niosi, 2003).

The initial commercial opportunities for biotechnology were presented from a number of breakthroughs in the early seventies, resulting from the discovery of the double helix structure of deoxyribonucleic acid (DNA) by Watson and Crick in the 1950s. The subsequent development of techniques for genetic engineering initially provided a new opportunity for developing processes to manufacture proteins. Subsequently, it has provided new tools for advancing the productivity of “conventional “small molecule” synthetic chemical drugs (Henderson et al, 1999).

Increasingly, the initial trajectories of the science of biotechnology have merged. The focus of human health biotechnology has moved towards using genetic engineering techniques, in the search for large molecular weight drugs, often proteins, for a particular therapeutic purpose. The focus on molecular biology moved pharmaceutical research into areas such as microbiology and biotechnology (Cooke, 2003) and also represented a shift in the knowledge base of the pharmaceutical industry (Henderson et al, 1999).

2.2.2 Commercial development of biotechnology

The development of small firm activities in European biotechnology has followed America’s lead. However, recently the number of European biotechnology firms has approached levels similar to those in the US (although these firms are often smaller in size). The UK has been one of the most active European countries in the development of biotechnology, in terms of company formation and finance (Howell et al, 2003).

A key feature of biotechnology development has been the creation of a large number of SME’s. SME’s have emerged to exploit opportunities for the commercial application of knowledge resulting from scientific and technical advances in biotechnology. Despite the

³ The Department for Trade and Industry was reorganised in June 2007 and now falls under the Department for Business Enterprise & Regulatory Reform (BERR). We continue to refer to the DTI in the text to reflect the department which was active during the period we analyse.

shift in the knowledge base of the pharmaceutical industry and the emergence of new innovative biotechnology firms aiming to exploit related advances, so far, incumbent pharmaceutical companies have not been swept away by these new entrants, as would be expected from a Schumpeterian perspective.

The result of the emergence of biotechnology SME has been a complex interaction and cooperation between a numbers of different players, from SME to multinational pharmaceuticals (Henderson et al, 1999). Much of the new biotechnology related knowledge originates from university research, which is often commercialised through spin out activity. Biotechnology SMEs play an important role, acting as innovators for the pharmaceutical industry. This has left 'big pharma' to integrate the lower order functions taking the "role of licensor and marketer of brought-in therapeutic treatments (Cooke, 2003). Florida and Kenney (1998) observed these dynamic interplays of small and large firms, universities, and formal and informal knowledge exchanges. They suggest it represents a "new model of innovation which integrates components of entrepreneurial-driven versus corporate-led dichotomy posed by neo-Schumpeterian theory" p.126. This positions biotechnology firms in the middle of relationships between R&D centres and multi-national pharmaceutical firms

The venture capitalist is an important agent in the interactions and relationships developed by a biotechnology firm. The venture capitalist operates to "facilitate commercialisation" of new knowledge, by providing finance and the strategic knowledge of how to reach the pharmaceutical market (Cooke, 2003). Niosi (2003, p.749) sees the commercialisation of biotechnology through spinout firms, as a process involving a sequence of milestones and collaborations where the venture capitalist plays a key role,

"The sequence starts with obtaining patents. These will signal to the financial community the value of the new firm. Patenting is followed by venture capital, entry into the stock market under the guidance of the venture capital firm, and the organisation of a major alliance followed by the launching of the firms products in overseas markets, usually with the help of large international corporate partners."

Niosi (2003) classes venture capitalists as external factors involved in the transition of a biotechnology firm from a collection of scientific knowledge assets, to a functioning firm that can demonstrate its potential to the wider financial community. However, in this role the VC can also help support internal firm capabilities by bringing external resources and competences into the biotechnology firm.

These discussions suggest that biotechnology commercialisation may present a certain type of entrepreneurship, which fills a role translating basic academic research into marketable forms. In this translation, the venture capitalists plays an important role in making the SME's products and services accessible for large multi-national firms to market, manufacture and distribute. This presents a much simplified picture of the industrial dynamics of the pharmaceutical industry and furthermore it is not clear whether this is a temporary or established industrial structure. However, we can, for the purposes of this thesis, see that biotechnology firms operate within a complex set of relationships between academia, large corporate firms and intermediary agents, such as venture capitalists.

2.2.3 The economic importance of biotechnology

In 1999 Lord Sainsbury's report for the Department of Trade and Industry on clusters of biotechnology companies stated the importance of the technology as follows:

"Biotechnology offers enormous opportunities for improving the quality of life and being a major creator of wealth and high quality jobs for the UK. The world market for biotechnology products is forecast to reach £70 billion by the year 2000, and biotechnology-dependent sales by UK industry to reach £9 billion. The sectors for which biotechnology holds most promise account for almost a quarter of all UK's industrial output, employment and export earnings – including pharmaceuticals, agriculture and food." (Sainsbury, 1999 p12).

The report added that around 40 000 jobs in the UK depended on biotechnology, and in 1999 there were around 270 small to medium sized enterprises (SME) specialising in biotechnology. It is also anticipated that factors such as an ageing population and the associated demand for pharmaceutical products will strengthen the market prospects for biotechnology products. Lord Sainsbury's report concluded that several policy measures were important to the development of the industry in the UK, specifically targeting, the promotion of entrepreneurship, the availability of finance, and the development of SME's.

Developing a strong biotechnology sector is seen to be an important economic tool for many developed countries, and therefore maintaining the availability of deep venture capital markets for biotechnology opportunities is an important political priority. Clearly venture capital has an important role to play in the development of the biotechnology sector.

2.2.4 Uncertainty of biotechnology

Like other hi-tech sectors, such as semi-conductors, investing in biotechnology business is high risk. For example, although biotechnology firms are businesses, they are science intensive and often active in the development of "basic biomedical science" (Pisano, 2006. p.2). There is high technical uncertainty in translating basic science into commercial

products and services. In addition to the usual activities associated with commercial activity, biotechnology firms frequently need to resolve scientific issues in order to demonstrate the feasibility or efficacy of the firm's product or processes (McKelvey et al, 2004; Pisano, 2006). Biotechnology firm R&D may deal with scientific issues that are fundamentally unknown and this significantly increases the level of risk (Pisano, 2006).

The emphasis on R&D in biotechnology SME results in lengthy product development times which increase the challenges of managing a biotechnology enterprise.

Biotechnology research is time consuming and the costs of undertaking research, maintaining laboratory space and paying for qualified staff are high. For example it may take many laboratory hours, using expensive technology and materials, to determine whether a research programme will yield important advances, or demonstrate the required properties for market (Pisano, 2006).

The risk (and costs) of running a biotechnology firm are also increased by the regulatory uncertainty, resulting from the close scrutiny, by national authorities, of new products. A new product must be thoroughly screened and tested in clinical trials before it can be marketed. The extensive regulatory process, necessary to make sure products are safe and effective, dramatically increases the development time and costs. For example, it is estimated that at the pre-clinical stage the probability of developing a single prescription drug through to launch is approximately 1%, for an outlay cost of £50-150m (Bioscience Innovation and Growth Team, 2003). These financial and time costs, together with the possibility of the failure of a product to meet these stringent tests, increase the risks associated with biotechnology (Pisano, 2006).

Pisano (2006) states that this type of uncertainty demands a mechanism to reduce risk. Biotechnology firms operate in a variety of relationships to reduce risk. Biotechnology firms develop various collaborations, strategic agreements and licensing arrangements with academic institutions, other biotechnology firms and large corporate firms to share the risk of research and development, gain access to important competence and resource (McKelvey et al, 2004) or to trade intellectual property assets according to their strategic plans (Pisano, 2006).

An important part of the biotech mechanism is the venture capitalist (Florida and Kenney, 1988; Bygrave and Timmons, 1992; Etzkowitz, 2005; Pisano, 2006). The high risks, long development times and significant costs make traditional forms of finance inappropriate.

For example biotechnology firms developing new pharmaceutical products may not produce revenue for many years, making repayments on loans difficult. Venture capitalists that fund biotechnology firms are expected to have a unique view of the industry with experience in understanding what makes a successful firm (Pisano, 2006). They develop capabilities that allow them to invest in and manage opportunities that provide an appropriate commercial risk to return balance.

2.2.5 Bio- entrepreneurship = venture capital+ human capital

Although the risks of investing in biotechnology are high, firms such as Genentech have demonstrated the commercial potential. Genentech is one of the most successful biotechnology companies in the world, with annual sales in excess of \$5 billion. Genentech is often regarded as the start of commercialisation of biotechnology.

Genentech also provides an important example of how venture capital can contribute to start-ups by providing early stage funding and acting as a pro-active technology gatekeeper. At Genentech the early stage investor joined the academic-scientist founder, to lead the company and help secure further 'patient' long term or 'classic' type venture capital (Florida and Kenney, 1988).

The 'classic' form of venture capital investment, particularly in biotechnology, demands a greater input from venture capitalists compared to other investments (Powell et al, 2002). The typical founders of biotechnology companies are scientists, and often lack some of the business skills and experience required to grow the firm rapidly. Kenney (1986) observed that the internal competences of entrepreneurial biotechnology firms matched Schumpeter's observation that there are four social roles critical to the creation of new entrepreneurial businesses: the entrepreneur, the inventor/scientist, the manager and the capitalist. Although, a combination of these different roles may be found in only one or two individuals involved in the start-up firm Kenney (1986) notes that,

"The entrepreneurial role in genetic engineering has usually been a partnership between an entrepreneur and a scientist. This is due to the very complex nature of genetic engineering. This division of labour reflects the new realities of both science and finance – only a specialist can handle either of these areas" (p.29).

The scientific and commercial demands of running a biotechnology firm mean it is likely that venture capitalists will take an active role in supporting the firm. For example Wright et al (1997) observed that successful entrepreneurs were often used by venture capitalists to improve the performance of their businesses by giving them non executive or consultancy type positions. Hellman and Puri (2002) find that venture capital backed firms

have high frequencies of replacement in the initial management team and that the venture capitalist is active in the management of the firm's human resources. Whilst Higgins (2005) study of biotechnology firms reaching IPO found that certain managers with particular career experiences or "Imprints" can be highly effective when applied in the bio-entrepreneurial context. These individuals were frequently recruited by venture capitalists to provide additional management skills in the biotechnology firm. Firms with the right mix of skills and experience are also likely to obtain better exits for the venture capitalist, particularly at Initial Public Offering (IPO) (Finkle, 1998; Higgins and Gultati, 2003).

In founding a company, those firms which offer good human capital coverage of key activities, including previous experience of the entrepreneurial process are more likely to be able to access venture capital funding (Zacharakis and Meyer, 2000; Burton et al, 2002). Biotechnology founders also recognise the importance of the availability of high quality human when choosing business locations (Bagshi-Sen et al, 2004). Bower (2003) notes that the maturity of the biotechnology sector has lead to the development of an infrastructure of expertise specialised in working with start-up biotechnology firms. In the UK, biotechnology firms typically include three founders with a mixture of scientific and commercial experience (Gurău, 2006); so we can expect the venture capitalist to be active in coordinating this specialist human capital resource.

In biotechnology, the transition from academic lab to commercial return is lengthy and strategically complex. Biotechnology investments add complications to the traditional venture capital process in terms of large financial and time commitments, and in terms of strategic decision making. These complications mean biotechnology firms are likely to benefit from the venture capitalists expertise in the entrepreneurial process. However, given that a VC may have other opportunities with short timescales and of lower risk, what motivates investors to take this role?

2.2.6 Investor motivations

For the venture capitalist, one of the primary motivations for investing in biotechnology is the large expected return when, for example, large institutional investors are prepared to buy shares in the company. The public flotation of a firm provides the opportunity for the venture capitalist sell their equity in the company and realise the growth in its value.

Pisano (2006) observes that despite the strong performance of several start-ups in the 1970s and 1980s, the overall performance of biotechnology is disappointing, with

relatively flat growth in profits. Importantly for venture capitalist exiting deals, the stock market performance of IPO biotech firms based on US data has performed better (15%). However, Pisano (2006) estimates that overall venture capital fund performance over an 18 year period (1986-2002) only achieved 16-17% annual rate of return⁴. This level of return is not commensurate with the level of risk involved in early stage investing vis-à-vis investing in public stock. The poor performance of biotechnology may present constraints for the attraction of quality investors and managers to the industry. For example experienced investors may prefer other lucrative healthcare opportunities. Similarly managers may prefer to work in more stable and lucrative large firms, rather than exchange good salaries for equity in a biotech business. Therefore, demand for specialist expertise in managing biotechnology firms may not be met.

2.2.7 Summary

In this section we have discussed two perspectives of biotechnology, firstly the view that biotechnology is positioned as an intermediate form. It is used to translate basic institutional research into viable business opportunities, where the outputs are distributed by large pharmaceutical firms. Secondly, biotechnology is a high risk enterprise, involving different forms of uncertainty; only confident investors will be prepared to provide funds on such a long term high risk basis.

We have described the process of developing an entrepreneurial biotech firm as a relational activity composed of different types of multi-level relationships which evolve with the development of the firm. These include working with universities, large corporate firms and other SME to help the firm gain access to new scientific knowledge and commercial opportunities. In addition, because of the predominantly scientific/academic nature of the knowledge required to start-up a biotechnology firm, we find that biotechs are expected to build relationships with venture capitalist. Firstly the venture capitalist provides access to finance, an important requirement for many biotechnology start-ups. Secondly the venture capital acts as an important intermediary in supporting the commercial development of the firm. This role requires the venture capitalist to provide expertise and have access to networks and contacts that can add value to the firm.

We have seen that venture capitalists and experienced professionals are important actors in the management and development of biotechnology firms. This review of the literature has shown that in order to understand the operation of venture capital and biotechnology we

⁴ Although clever investors who sold stock during the peak of the stock market bubble in 1999-2001 would have made much more.

must include the additional actors that provide guidance to early stage firms. However, in the UK we have noted an apparent weakness in the UK venture capital industry – it is frequently criticised as demonstrating a lack of technology awareness, experience, or willingness to experiment with emerging technologies. Similarly Oakey (2003b) observes that technology entrepreneurs can be slow to accept assistance from the business community and prefer to maintain greater control of their businesses, even if this leads to sub-optimal outcomes. Therefore, to what extent do we see relationships formed between venture capitalist and experienced bio-business directors in the UK?

This section has suggested the wider economic and social role that venture capitalists and experienced entrepreneurial professionals can play in supporting the development of innovative sectors such as biotechnology. Biotechnology firms are also known to cluster in specific geographical locations. One suggested reason for this is that concentrations of specialist firms are expected to facilitate access to the important relationships and resources we have discussed. It logically follows that our final section should at how venture capital is organised and how this relates to regional hi-tech activity such as biotechnology.

2.3 *Spatial concentration of the venture capital industry*

Venture capital is invested across the world; however the availability of venture capital within a country is often concentrated in a few key regional geographies. There are striking variations in the spatial distribution of venture capital investment within countries. This has been observed in both the United States and the UK. Whilst this has great economic and social benefits for a few ‘chosen’ regions, it may also present barriers to the development of other regions. In the UK, despite attempts by policy makers to encourage more even development, this has not occurred.

2.3.1 *Spatial concentration of venture capital in the US*

As the venture capital industry became established in the 1980s, Florida and Kenney (1988) observed that, in general, venture capital-financed innovation in the US was clustered around distinct types of financial or technological activity. Specifically, high levels of venture capital activity could be found in three types of centre, (i) technology-oriented centres involving a high concentration of research activity, (ii) in financially orientated centres with high levels of activity in financial services, or (iii) in a hybrid of (i) and (ii).

Technology-oriented venture capitalists are embedded in social structures of innovation, which provide the mechanism for “reproducing, highly skilled labour and continuously

mobilizing information” (p.130). This social structure also provides a means of learning about the financing of venture capital, and gaining access to types of information important in generating venture capital activity through networks, and resource sharing.

Financially orientated complexes are based in the financial districts in large cities and are often connected with large banking institutions. A much lower level of organisation takes place in these types of centres, and syndication provides an important link between complexes and technology centres. In this relationship the financially located venture capitalists often take a passive role, providing a significant amount of finance, but allowing the venture capitalist in the technology-orientated location to take the ‘lead’ (Florida and Kenney 1988). Syndication can lead to the formation of networks containing a “giant component that spans geographies and sectors” (p.4) that suggests the formation of linkages at a national level. Financial centres also provide wider access to financial capital in order for venture capitalists to raise funds to support new entrepreneurial firms.

The Florida and Kenney (1988) model suggests that in technology-oriented complexes, VC and their investments are co-located. Powell et al (2002) have observed that early stage US biotechnology companies received investment and support from local VCs, “while external [non-local] support flows to companies that have to ‘show’ more in order to attract financing”(p.303). In contrast to the ‘double paradox’, referred to in section 2.1.4.1, they also observed that “as venture capitalist grow older and larger, they invest more in both younger and more distant biotechnology companies” (p.303), in line with Bagshi-Sen et al (2004) observation that biotech firms compete for funds beyond their local region (p.209).

In general, investor proximity is expected to arise because of the result of the opportunity costs involved with sourcing new deals, the benefits of access to information from the local business community and the need to provide business assistance to their deals (Mason and Harrison, 2002; Zook, 2002). Lerner (1995) finds that a high proportion of those investors who take up board positions are local to the firm. Early stage companies will require more of the venture capitalist time, and may explain the focus on local venture capitalists.

2.3.2 Spatial concentration of venture capital in the UK

Less research has been made on the organisation of venture capital in the UK. The effects of geography on venture capital are not well understood (Mason and Harrison, 2002). In the UK, London and the South Eastern region receive a disproportionate share of venture

capital, compared to the total business population. Therefore, a company's location in the UK may alter the access to the amount and quality of venture capital received.

Martin et al (2002) suggest that the US model of a large successful venture capital industry based around clusters of high technology and localised investment may not be transferable to Europe. The authors suggest that Europe will not be able to support the development of high technology clusters on a similar scale to that found in the US unless each country decides to specialise in a particular type of hi-tech activity. Currently policy in the UK is aimed at achieving the opposite, instead encouraging "dispersed clustering" (p.143) to try and re-distribute the economic benefits of areas of high technology.

2.3.2.1 Influence of London

The organisation of the UK VC industry has featured a bias towards the South since the industry began to develop in the 1980s (Martin 1989). London is the UK's premier international centre of finance. The proliferation of international finance, the deregulation of the London stock exchange and the influx of foreign banks have maintained London's position in a national/international stage, and was "inevitable, therefore that the development of the venture capital industry as yet one more specialist division of the financial system should be focused there" (Martin, 1989, p.398).

The rush to invest in MBOs also built on the historical organisation of national industry in the UK. Many large UK firms had head-office locations in London and the South East. These large firms were potential targets for MBO activity and so tied many venture capital firms to operating in London. Investors based in London had to make larger investments on account for higher deal costs associated with operating in the capital. Therefore, by the end of the 1980s early stage investment had become a small part of the UK venture capital industry (Martin, 1989).

The concentration of investors in the South, including those investing in early stage businesses, may have created difficulties for investors to obtain information regarding opportunities elsewhere. For example, a lack of access to information and local networks outside the Southern UK region, may have contributed to a perception that opportunities in the North posed a greater risk. This perception of risk may have influenced the distribution of finance (Martin, 1989). Even firms like 3i with a strong local presence across the UK with 20 UK regional offices, still found their distribution of investment followed the national trend to the South (Martin, 1989). After 1994, the 3i business regional presence reduced to reflect their concentration of activities.

2.3.2.2 Role of public finance

Outside of London an alternative source of regional funding was provided by Regional Development Agencies (RDA's). Several RDAs were responsible for the creation of smaller funds operating outside London. Regional investors, providing early stage capital, have operated in the UK since the 1980's. Typically these investors were funded by nationalised industries or old metropolitan county councils (Sunley et al, 2005)⁵.

However, when public funding for these schemes stopped in the mid 1980s, several were privatised and looked for funding from the private sector (Sunley et al, 2005). Many of these investors operate today, such as Yorkshire Fund Managers and West Midlands Enterprise. In Scotland, Northern Ireland and Wales, the respective development agencies created their own venture capital arms. The Scottish Development Agency's VC arm is now an independent venture capital firm, Scottish Equity Partners, in which Scottish Enterprise retained a 25% stake (Hood, 2000).

Another source of regional investment resulted from RDA Training and Enterprise Councils. These Councils invested a combination of European Union and public-private finance. The private finance component was provided by Midland Bank (now HSBC). The aim for these funds was to target the perceived equity gap for SMEs. These schemes were supported by the Labour Government when it came to office in 1997. Since then, the Government has encouraged the development of a number of additional regional/local funds. These have included University Challenge funds which are designed to provide seed funding University spin outs, and a High Technology Fund which invests into other venture capital funds.

More recently funds have been created using public finance as a cornerstone to secure further private finance. These funds, run by private fund managers, include schemes such as the Enterprise Capital Fund, the Early Growth Funding Programme, and the Regional Venture Capital Funds (RVCF) scheme (Cooksey, 2006). In total nine regional venture capital funds (RVCF) have been created as general funds managed by experienced fund managers (Sunley et al, 2005).

The RVCFs were created to provide funding in the perceived equity gap at the start-up stage. They have also been designed to ensure each region's entrepreneurs and start-up

⁵ According to Sunley et al (2005) two examples of nationalised industry funds created in the 1970-1980s are British Steel Enterprise and British Coal Enterprise.

firms have access to a local VC funding and expertise. The expectation is that new funds will utilise the benefits from working in the local environment, such as access to deal information from local business networks, to overcome local information asymmetries regarding viable investment opportunities. The Government anticipate that these funds will demonstrate the potential, to other private investors, for commercial returns in these regions (Sunley et al, 2005).

However, doubts about the strategy of these funds have been raised. Firstly, the size of each fund, £15-30m, is too small to attract the quality 'hands-on' management of classic venture capital (Mason and Harrison, 2003). In fact the lack of qualified fund managers has meant that some regional players control regional funds outside their original home territory (Sunley et al, 2005).

Secondly, the limits to fund size, and a maximum investment of £500,000 per portfolio company, will restrict the level of follow-on investment which can be provided to firms. Firms that prove successful will need to obtain additional finance to drive companies rapidly through the development cycle to exit. The lack of follow-on funding may dilute the RVCF level of returns. A strong return performance will be necessary for the investors to raise new funds from private backers and achieve long term self-sufficiency (Mason and Harrison, 2003).

Finally, the scheme has not been well received by the private VC industry, as it is seen to artificially increase funding in regions where demand is not of high enough quality, diluting returns for all investors. The industry suggests that investment cannot be tied to a location, but should be free to invest where suitable opportunities exist. There also appears to be debate within Government departments regarding the RVCF's targets: uneven geographical supply; or a national approach applied at the regional level to relieve an equity gap (Sunley et al, 2005).

Ultimately, the UK Government has attempted to increase the amount of capital available for early stage investment. It has done this by including public finance in the creation regional venture funds. Given the previous discussions of finance and equity gaps this has positioned the Government as the providers of high risk start-up capital, but without the resource to follow the initial success stories through to the exit and reward. Consequently this may jeopardise the long term sustainability of the funds, which was cited as a driver for their creation.

2.3.3 Conclusions on the state of venture capital research

The geographical organisation of venture capital in the US shows clear patterns of development, based around institutional structures, such as Universities and financial centres. These structures provide important sources of skilled labour. Our literature review has shown a lack of research on factors influencing the organisation of UK venture capital. However, many UK policies have used venture capital as a regional development tool, to dilute economic concentration around London and spread economic benefits nationally.

It is widely recognised that the supply of venture capital investment is not distributed evenly across regions either in the US (Florida and Smith, 1993) or the UK (Mason and Harrison, 2002). This phenomenon has been researched following two complementary perspectives; firstly examining the characteristics of clusters of venture capital activity, and secondly by analysing the variations in regional supply and demand for venture capital.

Specifically, we note absence of a systematic study of the factors that influence venture capital investment in the UK. In Chapter 5 we build and test a model to explain the distribution of investment in terms of the result of factors provided in the literature which are expected to influence supply and demand for investment (Florida and Smith, 1993; Mason and Harrison, 2002; Martin et al, 2002; Martin et al, 2005). To help inform this model next we review the literature on industrial clusters and regional systems of innovation to help explain the concentration of venture capital activity.

2.4 *Venture capital and industrial clusters*

We begin with a review of the work on clusters, as this work can be linked back to Marshall's observations regarding the importance of particular locations for specific types of firms. We then build on this by reviewing the more recent literature on regional innovation systems.

2.4.1 Clustering in general

The definition of a cluster is not universally accepted within the literature (Morosini, 2004). For example industrial clusters can vary according to the nature of innovation process and structural conditions that concentrations of firms evolve from (Iammarino and McCann, 2006). Similarly clusters can evolve over time, such that places such as Silicon Valley which has grown from a localised cluster formed around strong local ties and relationships to a large agglomeration of competing firms (Iammarino and McCann, 2006).

The principles of the cluster concept are frequently based on Marshall (1925, cited Morosini, 2004 p.307). Marshall made three observations in an attempt to understand why companies continued to locate in the same geographical areas. The first point Marshall made was that the geographical closeness of companies generated mutual benefit in accessing a pool of specialised talent or human capital, where co-location created a skilled workforce which could meet the needs of an industry. Marshall also suggested that this close geographical location could deliver economies of scale in developing and utilising localised technology innovations or infrastructures, such as roads, termed “non-traded inputs” (Morosini, 2004 p.307). Finally, there was also a mutual benefit obtained from the flow of ideas or information, which could easily be exchanged when companies located in close proximity, as opposed to those in geographically dispersed locations.

Porter (1990, 2000) extended Marshall’s work to include a range of additional inputs such as the relationships between universities and business, management of the supply chain, and the mutual benefit of competition in a concentrated geographical region. Porter defines the cluster from a competitive perspective:

“Geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g., universities, standards agencies, trade associations) in a particular field that compete but also cooperate” (Porter, 2000, p.15).

Porter (2000) makes the point that the geographical scope over which clusters occur is related to the transaction efficiencies which result, and so can be regional, national, or international. For example clusters can vary in geographical size and concentration. Swann and Prevezer (1996) note that the distribution of biotechnology firms in the US is more even than for IT companies. Similarly Kenney and Patton (2004) find that supporting actors in biotechnology are also relatively more dispersed in biotechnology firms compared to other industries. In Europe the generally dispersed nature of clusters is anticipated to put them at a disadvantage compared to those in the US, as firm concentration is expected to increase the benefits of being located in a cluster (Martin et al, 2002).

Porter (2000) also argues that globalisation has reduced the locational benefits resulting from Marshall’s first and second points, meaning that knowledge flows, the development of local specialisations and social networks can create key sources of competitive advantage for firms, particularly in an Internet age. Similarly Morosini (2004) has also commented that:

“Basic production factors such as capital and non-specialised labour are largely open to all, whereas flows of specialized knowledge and rich knowledge interactions that lead to valuable innovation remain stronger between agents in the same spatial group than among geographically dispersed firms”

Recent studies, particularly of hi-tech clusters, have tended to concentrate on the interaction of knowledge flows and social networks, forming around the third Marshallian notion. Iammarino and McCann (2006) note that industrial clusters based on social networks can be categorised according to new and old types of social network. They relate the new type social network cluster to firms engaged in working with ‘sticky’ tacit knowledge, originating from new research, typically involving science based SME. The old type of social network cluster involves less technology innovation and processes are driven by customer demand. This second form of social network relies on relationships built up over time in the local area, such as found in the textiles industry. For example Storper (1993) found that the historical factors were important for low technology clusters in northern Italy. These clusters demonstrated mutual cooperation under highly competitive conditions. In contrast Leibovitz (2004) study of Scottish hi-tech clusters, also stresses the importance of historical legacy and cumulative processes for cluster development.

A key aspect of technology based clusters is the role of institutions that support their development, such as universities. Universities can act in a variety of ways to support the development of clusters. Firstly they can provide a source of knowledge that can be accessed or shared; secondly they can provide a source of innovation or knowledge with commercial potential. Finally they can be active in creating the necessary social conditions in the local environment through interaction and support of local innovative business and often academic founders to encourage the development of the cluster (Keeble et al, 1999; Leibovitz, 2004).

2.4.2 The clustering of biotechnology firms

Like other hi-tech firms engaged in basic R&D, biotechnology companies can be described as clustering for knowledge flows, to access the new scientific knowledge developed in universities and research centres, and to remain close to a constant supply of skilled labour and new ideas (Mytelka, 2004), therefore corresponding with Keeble et al (1999). In biotechnology start-ups there are frequently strong links between the start-up firm and local universities (Prevezer, 1997, Rickne, 2004), even if there are only partial previous ties to the university (Mytelka, 2004). The conclusion reached is that founders have a preference for maintaining existing relationships with local universities or research

institutes (Powell, et al, 2002). The preference to remain in a familiar location maximises the founders opportunity to develop local relationships and access to skilled labour (Keeble et al, 1999 Gertler and Levitte, 2005).

In many universities, academic entrepreneurship is encouraged (Stuart and Ding, 2006). However, in biotechnology we have noted that academic founders often display a lower level of business awareness when compared to other types of founders. This weakness is suggested to increase founder preference to remain local, as they are more reliant on local networks to help obtain finance and business assistance (Kaufmann et al, 2003). Therefore, the quality of local business expertise or human capital is important.

Similarly, the academic spin out process is not necessarily a linear transfer from academia to firm. Founders may experiment with different business models, such as licensing or services based activities within academia before deciding to pursue a spin out firm (Bower, 2003). It is possible that this iterative approach may encourage founders to remain close to their roots to preserve career options.

There are factors that may encourage scientists to move to new locations. For example we cannot rule out that key scientist with a particular commercial intention will move to locations that favour their commercial aspirations (Niosi and Banik, 2005). Also, as Bower (2003) points out, a lot of companies are founded by relatively senior managers from existing firms, who may also utilise contacts and networks gained from the parent firm in the initial start-up stages.

In general the literature on the clustering of biotechnology firms has mixed results regarding the importance localised inter-firm networking. This casts some doubt on the importance of the third Marshallian notion in terms of inter-firm networking in biotechnology. For example, Cooke (2003) notes that notwithstanding biotechnology industry's close ties to academia and particular key scientists (following Zucker et al, 1998) that local network relationships at the "individual firm level are less pronounced than might be expected given the obvious cluster concentrations in which biotechnology firms exist" (Cooke, 2003, p.762).

However, we find strong evidence to suggest that biotechnology will be concentrated around regions with a strong research base, and that bio-entrepreneurship is a locally based activity. The founder builds a business by using local contacts, connections and

knowledge of the local business environment and network, rather than relocate to unfamiliar areas (Feldman and Francis, 2003). In this way Zucker et al (1998) found that star scientists were able to use their reputation to attract great interest and the necessary commercial resources, to realise their potential of scientific discoveries. Finally, there are also benefits from remaining close to cutting edge commercial or academic research in the form of knowledge spill overs and externalities (Jaffe et al, 1993; Audretsch and Feldman, 1996).

2.4.2.1 Cumulative processes and Regional Systems of Innovation

The development of the biotechnology sector has not been evenly spread, with different countries showing pronounced variation in the rates of firm formation and cluster growth suggesting differences in the types of clustering activity (Walsh et al, 1995). Niosi (2003) suggests that (external) factors to support businesses may vary according to location. Similarly the presence of intellectual property and star scientists in a particular location does not automatically result in a cluster (Powell et al, 2002).

Only certain regions evolve to support a concentration of biotechnology business and a minority of locations evolve to become bioscience ‘megacentres’ (Cooke, 2004). In contrast to a cluster, whose focus is on competitive and co-operative links, a mega centre ‘capture[s] the full knowledge chain from exploration, through examination to exploitation of knowledge” (p.164) and therefore includes research institutes, large pharmaceutical firms and the wider group of supporting actors such as ‘knowledgeable attorneys’, consultants or venture capitalists (Cooke, 2004).

This wider view of the processes occurring within concentrations of firms has similarities with Niosi and Banik (2005) description of a regional innovation system (RIS) defined as, “geographical concentrations of interacting organisations (innovative firms, research universities, government laboratories and venture capital firms) aimed at the development of specific technology” (p.343). A particular region develops a regional innovation system as a product of routines relating to a particular technology or sector, producing a concentration of related organisations (p.346).

In Feldman and Francis (2003) study of the Capitol Region they find that the individual biotechnology entrepreneurs, in their creation and support of local academic spin outs, played a key role in shaping the development of the RIS. In pursuing their own individual interests, entrepreneurs acted as the ‘*critical element in the formation and the vibrancy of* ...

clusters of technology intensive firms' (p.780) by drawing together the necessary resources to support entrepreneurial firms in the region.

Following a similar position to Feldman and Francis (2003), Niosi and Banik (2005) suggest that as experience around a technology grows, intellectual property routines and technology transfer offices become established which attract venture capital to experiment with new opportunities. In doing so, venture capitalist learn how to market the technology such that it can achieve the credibility to support flotation on the stock market.

However this view of RIS assumes that venture capital is naturally attracted to a location or technology. As Von Burg and Kenney (2000) generally note, the academic literature often assumes that venture capital is available for attractive firms who demonstrate an understanding of the investor's criteria. Instead, Von Burg and Kenney (2000) suggest that venture capital must be actively recruited by the firm; there are no guarantees that any particular firm will obtain finance. In agreement with Feldman and Francis (2003) this emphasises the important role of regional demand from entrepreneurs for VC.

2.4.3 Processes within and across regions

Our discussion to this point may suggest that biotechnology clusters will only arise in regions which are able to learn how to develop the interactions of local entrepreneurs, firms and institutions. Clusters that are able to foster this type of cumulative learning process, involving the continual "integration of up-to-date tacit knowledge into innovation processes," may maintain or further develop their "competitive edge" (Cooke, 2004, p.175).

However, RIS do not exist in isolation. Important knowledge and information may be sourced from outside the RIS (Niosi and Banik, 2005). For example, large companies of strategic importance may be located outside the region in focus; equally firms located within particular clusters may have strong national or international relationships, particularly when it comes to accessing cutting edge specialist R&D knowledge (Mytelka, 2004; Cantwell and Iammarino, 2000).

As we have noted in previous sections, for a variety of reasons the literature suggests that biotechnology firms are co-located with concentrations of venture capital as a result of a co-evolution of money and ideas (Powell et al, 2002). As the founders of biotechnology firms often lack commercial experience venture capitalists are required to help supply the necessary business skills and experience, and this may further encourage the co-location of

biotechnology and venture capital (Powell et al, 2002). In support, Zook (2002) finds that venture capitalist prefer to invest close to their own office locations; proximity allows them to efficiently exploit their social network, as a resource for supporting entrepreneurial firms.

However, Niosi and Banik (2005) note the syndication of venture capitalists may draw finance from investors in other areas. Similarly Kenney and Patton (2004) find expertise for supporting hi-tech firms may be sourced from beyond the region. For example actors supporting entrepreneurial biotechnology firms, such as non-executive board advisors and investment banks were often located over 50 miles from the biotechnology firm. In comparison to other sectors such as semi-conductors, co-location in biotechnology was less prominent.

However, we can find agreement between Kenney and Patton (2004) and Powell et al (2002). Kenney and Patton (2004) base their analysis on the board membership of biotechnology firms at IPO, which are generally older and more established firms. Powell et al (2002) have shown that venture funded biotechnology companies based away from venture capitalists, were generally found in older and more established firms.

2.4.4 Summary

In support of the third Marshallian notion we have consistently found that universities and research institutes are at the centre of biotechnology firm activity (Prevezer, 1997; Feldman and Francis, 2003; Cooke, 2003). Biotechnology firms concentrate close to universities and research institutes to benefit from specialist knowledge and skills. In doing so they also rely on previous contacts and knowledge of local networks to which can be used to help the start up firm. The focus on sources of technology and local networks partially matches with the Florida and Kenney (1988) models technology complexes and venture capital.

We also observe the multitude of relationships that exist around biotechnology firms that McKelvey et al (2004) believe to be one of the stylized facts of biotechnology. We find reference to 'academic' relationships between research institutes, individual academic entrepreneurs, and the firms they go on to build at a local level. However, in contrast to the industrial clusters the literature identifies weak local relationships between different biotechnology firms, and between biotechnology firms and large corporations.

We have discussed how a wider variety of relationships support bio-entrepreneurs, both locally and further afield. The venture capitalist is described as being important for supporting entrepreneurial firms. In line with the Florida and Kenney model of venture capital, the RIS literature describes the venture capitalist as an important part of the regional system, but not necessarily local. They intermediate between financial capitalists and innovators, using commercial expertise to help businesses move from the scientific to the commercial world.

The literature indicates that clusters of firms are a result of regional activities, such as strong R&D activity, high quality human capital, and entrepreneurship which also suggest these places maybe attractive for venture capitalists. However, VC funds rely on contributions from other types of investors, encouraged by access to strong financial communities. The industrial cluster literature suggests that regional supply of venture capital would be strengthened by local financial activity. Florida and Kenney (1988) allow for venture capitalists to interact between technology and financial complexes. The RIS literature includes reference to the role of investors and the wider financial community, but is less clear about co-location. In Chapters 5 and 6 we explore whether the concentration of investment activity can be directly related to regional activities. In Chapters 7, 8 and 9 we refine our analysis using the region as a tool for exploring the organisation of UK venture capital activity in detail.

Clearly regions with strong networks increase the flow of information between entrepreneurs and the business community, including investors, and help to connect investment supply and demand. At a detailed level the venture capitalist is strongly associated with relationships and ultimately networks. The venture capitalist can clearly be described as an intermediary, between finance and innovation. However, the venture capitalist is also shown to act at the centre of a variety of relationships, as an investor, a board director and as a social networker, to bring together resources to support the entrepreneurial firm. As Zook (2002) suggests, venture capital, like Martin's (1999) observations regarding money and finance, can be viewed as a social relation. In the regional systems of innovation literature, the dynamics of venture capital based relationships have not been adequately explored.

In this chapter we have discussed the literature relevant to the development of the thesis and shown how we position the research questions to focus our analysis. The view of venture capital operating on the basis of social relationships that help investors achieve

purposeful outcomes has strong resonance with the literature on social capital. We conclude this chapter by stating that it is clear that more work is needed to understand regional networking activity involving venture capitalists and other business actors that support the firm. Our next step is to review the literature more generally on network concepts and theories to provide a more comprehensive understanding of networks.

3 Networks in venture capital

In our literature review on venture capital and regional innovation systems we find networks are an important part of regional activity. Frequent interactions or ties between proximate actors are thought to be one of the mechanisms through which clusters offer companies competitive advantage. The emphasis on ‘systems’ in the regional innovation literature also implies that innovative regions function as a product of relationships between different actors.

In this chapter we review the different theoretical literature relating to networks, and begin to answer research question two proposed in Chapter 1. We start by asking what networks are and why are they of value? Then we consider the role and value of networks for entrepreneurial SME firms and venture capitalists. We summarise our discussions by presenting a networked model of venture backed entrepreneurial firms. Finally we investigate the social network literature in view of interpreting network structure and variations in the type of ties.

3.1 What are networks?

A network is defined as a set of agents, such as individuals, firms or institutions linked by a set of relationships (Gulati, 2007). The relationship between two agents, for example between individuals, firms or mixture of both, is the basis for building networks (Scott, 2000). Knoke and Kuklinski (1982) stress that relationships are not, *“an intrinsic characteristic of either party taken in isolation but an emergent property of the connection or linkage between units of observation”* (p.10). Thus relationships can be viewed as a joint property between two agents.

The analysis of relationships can be used to investigate the “structure of social action” (Scott, 2000 p.5), where relational data, the contacts, ties and connections relate between agents, rather than about specific agent (Scott, 2000). Thus relationships between agents are conceptually distinct from the attributes of the same group of agents. Many aspects of social behaviour could be treated from either a relational or attribute perspective (Scott, 2000), but the choice of measurement option is “neither polar nor mutually exclusive” (Knoke and Kuklinski, 1982. p.10). For example, it may be the case that structure of an individual’s network relations may interact with some measure of their attribute such as wealth or status. Importantly, analysis of the attributes of individuals in a network will not provide the same information as analysis of the relationships in the same network.

3.2 What do relationships achieve?

In the final part of Chapter 1 we introduced the idea that relationships are important.

Social capital theory suggests that relationships are an important means of achieving useful actions. In this section we discuss the relevance of social capital to entrepreneurial firms.

3.2.1 Social capital

Starting from the perspective of any given individual, the theory of social capital is – “the capital captured through social relations” which are a “social asset by virtue of actor’s connection and access to resources in the network or group of which they are members” (Lin, 2002 p.19). The distinction between social capital and personal capital is clear (Burt, 1992). Personal or human capital rests with the individual’s possessions, skills abilities and money, whilst social capital is based on relationships (Lin, 2002). Social relationships come “into existence when individuals attempt to make best use of their individual resources”. Although social capital resides in relationships it can be seen as providing access to resources which can be utilised by the individual (Coleman, 1990. p.300).

We can view social capital as the starting point for examining the theoretical perspectives relating to networks, as all individuals share some level of social capital through their interaction with others. It follows that social capital theory predicts that social networks formed by the relationships between actors can enhance the outcomes of actions (Lin, 2002). Social capital also introduces the idea the individuals do not act in isolation (Coleman, 1990).

The literature suggests various mechanisms through which social capital can influence the success of actions for an individual. For example individuals investing in social capital may benefit from the flow of information from other agents. This can open up new opportunities or help reduce potential search and transaction costs. By creating ties with others, an individual increases their access to information from new sources or overcome imperfections in the market in terms of geographies or hierarchies (Granovetter, 1973, 1985; Burt, 1992).

Social ties also have the potential to influence critical decision making. Social ties to the right individuals may carry weight in terms of credibility. A tie to an influential individual maybe important if they are prepared to ‘put in a word’ on your behalf (Lin, 2002). For example an entrepreneur with a relationship to an important industry contact, may benefit directly from their knowledge and experience, but may also gain access to other relevant associates or resources as a result of the social tie. Burt (1992) attributes value to

connections that create competitive advantages by providing information and access to resources which would be unlikely to become available otherwise. They can be particularly valuable if these relationships are generally unavailable to others, and therefore overcome “structural holes” where few relationships exist in a network.

As Lin (2002) highlights, three elements of social capital include: the size of a person’s network in terms of the number of people who would help you when required, the strength of their readiness to help and the resources of these contacts. Therefore social ties of an individual can provide some appreciation of their grand standing or their wider access to resources, which makes them more valuable than the aggregate of their own personal capital. It also follows that developing ties within a particular group with shared interests and resources, the associated social capital formed within the group may re-enforce members “identity and recognition” (p.20). It follows that membership of a group may also promote an individual’s worthiness, indicating their access to resources associated with other members of the group (Lin, 2002).

3.2.1.1 Social capital of groups

An alternative view, which still appreciates that social capital mechanics operate at an individual level, has been proposed by researchers such as Bourdieu (1986), Coleman (1990) and Putnam (1993). These authors have been interested in the overall dynamics of groups of connected individuals, to understand how social capital can function as a group or collective asset.

Lin (2002) summarises that social capital, according to Bourdieu (1986), is based on the idea it provides a useful resource for individual members of a group. Members of the group mutually invest in relationships with other members of the group accumulating credits. When required, they can call down on their credits to gain access to the resources of other group members. In this way social capital is fungible, but an individual’s resources have to be exchanged to acquire useful social capital within the group. However, Coleman (1990 p.302) believes social capital is only fungible with regards to specific activities, and valuable for creating only certain actions relevant to a given individual. In Coleman’s view of social capital actors have direct interest where they apply their own resources, but also shared interests in events or actions that are partially controlled by others (Lin, 2002). Therefore individuals engage in a trading or exchange of resources through their social ties, to satisfy their own interests or achieve certain actions (Lin, 2002).

Furthermore as Portes (2000) observes there are contrasting views of social capital as an individual, group, or collective asset that leads to different views on the function or value of social capital. At the collective level social capital is theoretically weaker as it becomes difficult to separate social capital from other broad types of activities or individual traits. From this perspective social capital risks becoming an explanation for all that is good in society (Portes, 2000). For example, regional economic performance can be explained by social capital following Putnam's focus on 'civic spirit', but it is also possible that the civic behaviour is a result of the economic performance which binds people, or that a factors such as strong local education has promoted a sense of civic duty and economic success (Portes, 2000). Thus we should be cautious when talking about social capital and positive outcomes as the two may be interrelated. However, we can expect an undirected relationship whereby the aggregate network structure of a region will be associated with properties or characteristics of that region.

It is clear that relationships and ultimately networks are fundamental to the development of social capital. Lin (2002) suggests the social capital maybe defined operationally as "the resourced embedded in social networks accessed and used by actors for actions" (p.25). Individuals create ties to one another as a natural process of trying to achieve purposeful actions. During this process, the potential exists to develop and accumulate social capital. Therefore social capital comprises of resources based within relationships, but where access to these resources is managed by individuals.

Extending this further, Lin (2002) observes the consensus view that social capital, "as theory generating concept should be conceived in the social network context; as resources accessible through social ties that occupy strategic network locations, and/or significant organisational positions" (p.24). This view naturally suggests that a precursor to the analysis of social capital is to understand the network relationships that exist between actors.

3.2.2 Relationships and a theory of social capital

Whilst it is possible for individuals to invest in social capital by maintaining relationships, they can only realise the value of social relations from connections they are aware of (Lin, 2002). It follows that a natural part of sustaining relationships and the utility of any social capital represented by them, is a certain amount of obligation between tied actors, in terms of reciprocity or compensation (Coleman, 1990).

Cohen and Fields (1999) see social capital as facilitated by trust, where trust is based on performance, reliability and reputation. For example they view social capital networks in Silicon Valley as focused, productive interactions among [...] social institutions, instruments and entities” (p.193) which include Universities, venture capitalists, law firms and business networks influenced by the structure of local industry. In their view social capital is maintained through the productivity or performance of ties.

3.2.3 Network approach to entrepreneurship

The discussion of the value of networks and social capital shares a similar perspective to “network approach to entrepreneurship” coined by Brüderl and Preisendörfer (1998).

Researchers in the field of entrepreneurship have long noted that networks make an important contribution to the field. For example entrepreneurs with larger, more diverse networks will be able to obtain more support for their projects and ventures, than those entrepreneurs with small networks (Witt, 2004). Sorenson (2003) sees social relationships as important for an entrepreneur to access range resources such as tacit industry knowledge, human and financial capital. In the network success hypothesis, networks based on founders personal and business relationships can be used to acquire information and resources that may generally be unavailable or more expensive if obtained on a market (Brüderl and Preisendörfer, 1998).

Diverse networks can support the entrepreneur in the production and delivery of goods and services. In the initial phases of development a start-up founder is likely to use their current social capital and trial and error approach to develop their network of ties on an interpersonal level (Larson and Starr, 1993). The connections which prove useful to the entrepreneur in running their business become of value and reflect the entrepreneur’s social capital. In this way relationships become a useful resource for the firm (ibid).

Entrepreneurs can adapt and manipulate their network in terms of size, access to resource and information by building the right relationships to suit their needs (Greve and Salaf, 2003). In particular, having contact with other entrepreneurs operating at a national or international level can provide access to a range of contacts and improve business growth (Donckels and Lambrecht, 1995).

The utility of social networks is thought to be one explanation for the ability of entrepreneurial firms to grow and to compete with larger firms. The flexibility of informal relationships mean entrepreneurs can hold on to useful connections and build long term relationships (Johannisson, 1996 cited Schutjens and Stam, 2001). The ability to develop

social capital to provide access to resources can compensate for the liabilities of the start up in terms of their size, such as restricted firm level resource and a lack of historical legitimacy. Applying the network success hypothesis, those that access resources more cheaply than their competitors could via the market, will be more successful (Witt, 2004).

3.3 Summary

Although we find different perspectives on the organisation of social capital, at the individual, group or regional level, the consensus view is consistent; that relationships have value and are an important resource. Actors are motivated to create ties aligned with their own interests. However, in following their interests, they also collectively form indirect ties with others, resulting in the formation of networks. Therefore networks capture the wider social structure of actions.

In line with our discussions in Chapter 2, regarding regional networking to support SME, we have shown that networking is an important part of the entrepreneurial process. A crucial ingredient in building new firms is developing relationships to provide access to resources. In sectors like biotechnology, we anticipate that new business founders may have access to social capital that is tied to academic success, but not necessarily business success. There is clearly a role in the entrepreneurial process for an experienced entrepreneur or firm director, whose access to social capital and stock of social ties can usefully be applied, to provide access to a range of commercial contacts and resources to support the firm.

This section indicates the importance of non-financial contribution of actors in regional innovation systems like venture capitalists. We know from Chapter 2 that part of the activity of being venture capitalists requires building networks to obtain information on opportunities, finance and potentially other resources from the investment community. Agents, such as venture capitalists with many relationships to others, can be expected to develop a network of contacts that provide access to valuable resources to help their investments.

Another important actor that supports entrepreneurial firms is experienced directors. Directors of venture backed firms often hold greater power over management than in other SME firms, having control of the finance and also the expertise. Venture backed boards often have more outside directors, who take an active role in managing the strategy of the firm (Rosenstein, 1988). Directors of SME firms, that are brought into the firm after start

up can bring prestige (Mizruchi, 1996), guidance and advice (Daily and Dalton, 1992) and training for the other directors (Deakins et al, 2000). It seems likely that individuals with multiple SME directorships will have accumulated important human and social capital, which can be used to develop important relationships for entrepreneurial firm. In the next section we consider the implications of social capital and networks in view of the investors and directors of venture backed entrepreneurial firms.

3.4 Relationships between entrepreneurial actors

Our discussion of social capital suggests that individuals with entrepreneurial type social capital should be in demand to fill positions in entrepreneurial firms. This is particularly true for venture capital backed firms. For example Higgins (2005) found US VC's often recruited business executives to lead their biotechnology investments. Higgins (2005) shows that the success of a particular group of healthcare executives, who shared similar backgrounds and experiences, was partly due to the presence of strong ties to each other, and the relevant business community.

In-demand directors are a feature of corporate activity. Useem (1984) suggests relationships formed by directors shared between the boards of large corporate companies are extensive. Director ties between firms are known as interlocks (Mizruchi, 1996). Typically between two thirds and three quarters of US and UK non-executive directors are also top executive directors in large corporate firms. Useem (1984) observes that multiple interlocks make directors more valuable, as it connects them with the business community. Their multiple appointments provide them with a 'business scan', obtained through a range of experiences and contacts in business that can aid their strategic and operational insight and input. Research has shown that directors with multiple interlocks are more likely to be selected for new board positions (Davis, 1993 cited Mizruchi, 1996), and contribute positively to firm performance (Harris and Shimizu, 2004). Although Mizruchi (1996) and Johnson et al (1996) indicate variation in the literature regarding the motivation for interlocking, research generally suggests that experienced directors play an important role at the firm level.

The concept of director 'business scan' matches with Rosa and Scott (1999). They find at least three quarters of SME high growth firms in Scotland were associated with one or more directors who sat on multiple firm boards. They also found successful entrepreneurs pursued related diversification to grow several related businesses at the same time. Similarly, Storey et al (1987, cited Rosa and Scott, 1999) found that 80% of directors of

fast growth firms owned other businesses, compared to 30% in the remainder, supporting the role of directors with 'business scan' in entrepreneurial firms.

In summary we find an alternative measure of entrepreneurial performance involving 'clusters' of firms linked by entrepreneurs and firm directors. The network approach to entrepreneurship also emphasises the importance of social networking between entrepreneurial firms, where relationships are created by between individuals that help to facilitate the entrepreneurial process. Combining these perspectives it should be possible to identify networks of individuals active in supporting entrepreneurial firms, who are related by shared ties to the same firms. In this way a network approach is a complementary technique for understanding the wider industry dynamics occurring within an entrepreneurial sector.

3.4.1 Inter-investor relationships

A different type of relationship is formed when a venture capital firm decides to finance an entrepreneurial firm. An investment agreement between the venture capitalist and the firm creates an inter-firm relationship. If another investor also provides funds to the same firm then two additional relationships are formed. Firstly between the second investor and the firm, and secondly between the two investors who are affiliated to the same firm. Wright and Lockett (2003) indicate that where two or more investors finance the same firm, then they work together as a syndicate.

The relationship(s) between venture capitalists in syndicate may closely resemble a joint venture, where investors may jointly have some level of control over the SME. A syndicate is usually involves two or more VC firms taking an equity stake in the same investment round for a joint payoff, known as an equity syndicate (Wilson, 1968). However Brander et al (2002) also propose a broader definition of a syndicate, involving several investors providing funds to the firm over different periods of time.

A syndicate of venture capital investors can be expected to involve formal and informal relational components. A formal investment agreement details the rights of each participant and their financial commitment, and is used as a backdrop upon which to operate the syndicate. However, the active management of the syndicate is likely to be based on more informal relationships between investors involving the discussion of the investment strategy and future expectations for the firm (Wright and Lockett, 2003).

Research is in agreement that syndication and frequent changes in firms leading and following in investment syndicates create a network of partners (Bygrave, 1987, 1988; Wright and Lockett, 2003). Over time a “*dense inter-firm network may be created*” based on syndicated relationships between different investors (Manigart et al, 2006. p.135). As informal relationships between investors outlive any formal agreement relevant to a single deal they help minimise opportunistic behaviour by the lead investor. For example an investor’s reputation is important for gaining access to future syndications, as many deals are organised on the basis of referrals from other investors (Bygrave, 1987, 1988). Thus informal relationships are important drivers of the patterns of syndication between investors (Wright and Lockett, 2003).

Therefore, although individual deals have a strong formal component, the overlapping ties which result in syndicate networks, strongly represent social ties between investors. In agreement with Grandori and Soda (1995) formal networks are often supported by more informal or social networks. They define social networks as organised without legally binding agreements. However, it is important to remember that only same firm board positions create a direct linkage between venture capitalists in this way.

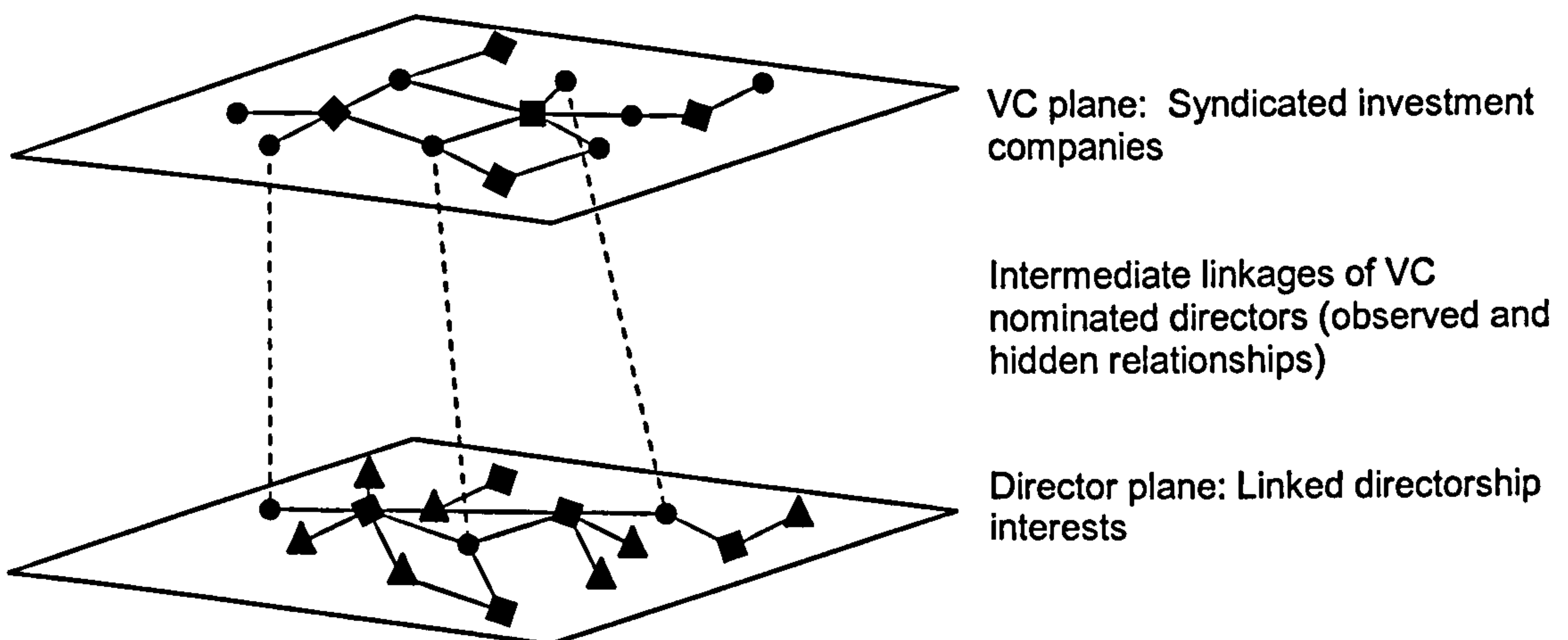
In agreement with our discussion of social capital, we find relationships between investors to have value. In particular, ties between investors have strong influence over future access to deals. We can expect that VCs are situated in a network of past and present affiliations with other investors. This is supported by research that suggests syndication networks are an important means of disseminating information regarding investment opportunities in different geographical regions. Without the network it would be difficult for investors to gain access to opportunities outside their main locations (Manigart et al, 2006 p.135).

A special type of relationship can arise in a venture capital backed firm, when an investor or investment company provides a director to the entrepreneurial firm. The literature in Chapter 1 proposes that a key activity that separates venture capital from other forms of investment is the specialist monitoring and advisory role performed by investors (Wright and Lockett, 2003). To manage their investments venture capitalists frequently reserve the right to take a board positions in their portfolio firms. They may choose to take up the position themselves or use a trusted non-executive director. Similarly, the US literature suggests that a core component of the value adding services provided by VCs to the firm is the recruitment of high quality human capital, to help guide the business forwards, and

social capital in the form of access to other external contacts and relationships. These value adding activities may be provided by the venture capitalist (usually the syndicate leader) or through the appointment of an associate of the investor. It is expected that these value adding services are also formally recognised through the appointment of directors to the board of firms.

3.4.2 Network conceptualisation

Based on our review of the literature thus far we can propose the following conceptualisation of interactions involved in venture capital – entrepreneurial team dynamic, as shown in the diagram below. Although it may not capture the complete variety of relationships found in venture capital, it provides a useful framework for further analysis.



The diagram shows two levels or planes of activity. The top plane shows the investment relationships of venture capitalists (dots) with entrepreneurial firms (squares). The second plane is similar to the venture capitalist plane, in that it contains the same population of firms, but includes the directors of the entrepreneurial firms (triangles) which can also include the venture capitalist director or a nominated representative. The two plane representation separates the network of investors from the network of directors. It is clear from the literature that a key component of venture capital deals is the application of value adding services to improve the performance of the entrepreneurial firm. This leads to the final type of relationship shown in the diagram; the intermediary linkage between investor and director planes. This creates a link between the investors and the directors.

Our previous discussions highlight the importance of a range of technical and commercial expertise in the entrepreneurial process. This is emphasised by the importance placed on the human capital in the venture capitalists assessment of investments. Those individuals

with experience and contacts which can help entrepreneurial firms develop, will be in demand.

We also expect that relationships are an important means of obtaining resources for the entrepreneurial firm, but the distribution of social capital across individuals is unlikely to be even. This raises an important question regarding the influence of social capital on the structure of social networks.

3.5 *The structure of social networks*

It is clear that the theory of social capital and the social networks perspective are closely related. A first step towards understanding social capital is to simply understand the network of relationships. Nahapiet and Ghoshal (1998) view social capital in terms of three dimensions, the first, structural social capital, relates to structure of the whole network, such as its configuration, density of ties and how different actors are connected. Their second dimension, relational social capital, is derived from the different types of personal relationships which develop between individuals, such as trust or friendships. Different types of relational social capital in a network may influence the behaviour of people, such that even if two networks are structurally similar, they may lead to different outcomes. The final category is based on a cognitive dimension that relationships represent resources that have a “shared system of meaning” or shared interpretation, such as a shared language or code (p.244).

Our focus in Chapters 7-9 will centre on the structural and relational social capital in venture capital networks. Social network analysis provides a method of representing and analysing social network structures. Although the techniques of social network analysis are frequently applied in academic research, there is less congruence in terms of a core theory regarding social networks; instead a pattern has emerged of the use of network terminology and techniques applied across multiple fields in different contexts.

The themes of the thesis include combining an analysis of relational and geographical perspectives. This section will examine social network analysis tools, general mathematical network models and common characteristics of social networks as well as the links between clusters in terms of network and geographical space.

3.5.1 Network structures

Modelling networks mathematically provides an abstract approach to understanding networks, regardless of whether the unit of analysis is at an individual or firm level.

Importantly mathematical explanations for the general structure and formation of networks also demonstrate how different network structures influence the flow of information and knowledge around a system, which relates closely to our discussions in Chapter 2.

The mathematician Erdős (Watts, 2003) proposed that networks can be modelled as the result of random processes. If we have a group of actors, and randomly create ties between any two agents, then as new connections are added, eventually the point is reached where each agent on average has a random connection. At this point, adding new connections between members of the group rapidly increases the connectivity between actors. As the number of relationships added increases, the number of unconnected agents decreases exponentially, quickly resulting in single giant component that can be called a network (Barabási, 2002). In a network, it is possible to move from one agent to the other, through the relationships that connect them.

In a random network the number of relationships held by each agent will follow a Poisson distribution, with each agent tending towards an average number of relationships. The theory doesn't describe the mechanics of how the relationships are made, but is intended to model the overall structure of networks. Random networks have been found appropriate for describing many complex networks (Barabási 2002).

The random network model, suggests a uniformity of network connections and an even distributed of ties between actors. It also suggests that any apparent sub-structures in the network occur randomly, rather than as a result of any geographical patterns in the location of actors. In random networks, on average, path lengths between any two actors are short compared to the Ising network and result in effective diffusion of information (Cowan, 2004).

The Ising model is the opposite of the random network. In the Ising model ties occur between agents located in the same physical space. Links are created between nearest neighbours in a geographical sense. The result is a network formed of overlapping local clusters. In this network the average path length between any actors is long, as links across distant clusters do not arise. For example, for information to reach distant parts of the network it must travel through each successive local cluster on the way (Cowan, 2004).

An alternative view of networks, which is a compromise between the random and Ising model, is described as the 'small world' phenomenon. Small worlds are a characteristic of large networks that have sparse networks without any form of dominant central control, but also contain areas of highly clustered linkages. The surprising observations made when researching these large networks, was that it was possible to connect two actors in the network with a relatively low number of intermediate nodes (Watts, 1999). For example it is suggested that it only requires six people to connect two randomly chosen people in the world (Barabási 2002).

Small world networks have been found to describe innovation networks, involving patent citations or R&D alliances. In these knowledge based networks, a small world structure represents a trade off between rapid dissemination of information found in random networks and the facilitation of knowledge sharing and the production of innovation found in localised clusters or Ising networks (Cowan and Jonard, 2008). For this thesis we might expect small world structures to be a feature of UK venture capital networks. In this case localised clusters of investment and entrepreneurial activity are loosely linked together to form a national network and would suggest an efficient national structure of linked clusters.

However, both the random and small world networks fail to predict networks which contain a small minority of agents have extremely high number of connections. These networks contain actors who act like hubs and result in centrally organised networks. These highly connected minority agents have important network properties, in particular they can act as important connectors to other actors in the network. Hubs have an interesting property in that they considerably reduce the network distance between actors in the network, more than in the case of small world networks. As highly connected actors in the network, hubs strongly influence the network structure and have implications for the flow of information around the network (Barabási 2002).

Networks which display the hub type properties, instead of showing random or small world characteristics, can be modelled according to power laws. The frequency of agent's connections in a network will follow a power law: the majority of nodes have only a few links, whilst a small minority of nodes have a vast number of links. We call the number of direct ties a vertex has to other vertices in the network, the "degree". A vertex of degree three has connections to three other vertices in the network. By plotting the frequency distribution of vertices degree in a network we can gain insight into the network structure.

A power law distribution can indicate that the structure of the network is a hub and spoke type system.

The degree of a vertex is one measure of its network centrality, i.e. the more central an investor in a network, the higher the degree. Clearly actors in the network who act as hubs will have a high degree and be described as central. However degree centrality only provides a relatively localised assessment of network centrality as it only considers the direct ties an actor has, for example a hub may have relationships with one particular part of the network. Other measures of centrality reflect an agent's position in the wider network, by considering the indirect ties, i.e. the connections of the network actors to which a hub maybe attached. These measures are known as betweenness and closeness (De Nooy et al, 2005).

A further consideration is that networks grow and change over time. If the growth of networks is considered, then the idea of preferential attachment becomes important to explaining the formation of hubs, simply that networks connections are not made in random, but follow a measure of popularity. New connections added to the system will be more likely to link with established hubs. The growth of networks therefore favours the early movers who establish a core of relations. The subsequent growth of the network through the entry of new nodes can be shown to be attracted more strongly to the established nodes. From this, hubs will develop, such that each node attracts links at a rate proportional to its current links – following a power law (Barabási and Albert, 1999; Barabási, 2002).

In contrast to random networks, the concept of an average node fails to capture the structure of hub and spoke or preferential attachment type networks. Similarly, an increase in the size of the number of agents in the network will not change the structure of a preferential attachment network. The power law distribution will remain fixed, so effectively these networks are scale free. An example is the World Wide Web. The web is a large network where certain sites have extremely large number of connections to other web sites, whilst the majority have only a few, and so can't be explained as being random (Barabási 2002).

Our discussion highlights that networks can be highly organised with well defined properties and sub-structures which influence the overall structure of the network. Clearly our discussions in this chapter represent several idealised or models of networks. For

example, according to Cowan (2004) it is possible to find some presence of hubs like structures in small world networks. Like hub based networks, small world networks are also characterised by some skewedness in the distribution of the degrees of actors. It is conceivable that an actor may connect across many other actors distributed across different clusters. Thus, in reality it is likely that real world networks will often fall between predicted model types. In line with social theory, networks can be analysed according to their sub-structures, in the next section we bring together literature on social capital theory and network structure.

3.5.2 Social capital and network sub-structures

Social capital theory can be used to describe the characteristics of an individual's social capital, in terms of their reach and access to most valued resources, the heterogeneity of the breadth of their relations and resources, and finally the overall size of their reach as defined by the number of contacts they have.

The theory of social capital as proposed by Lin (2002), predicts that society is organised according to individuals structural positions along a spectrum of access to resources, class, power and authority. This view of society suggests that a structural advantage will exist for individuals higher up the positional scale. Higher positions will yield a greater access to the most valuable resources and provide a relative network advantage over lower structural positions. It also predicts that those sharing structural positions will have similar characteristics and potentially ties to similar agents. It follows that ties within structural positions are formed more easily than across them. The closer people's social positions, the more likely they are to form a relationship.

Lin (2002, p.60) proposes that the "primary proposition of social capital theory suggests that the success of an action is positively associated with social capital", it follows that a "simple strategy to accomplish a purposive action is to access an actor who possesses or can access more highly valued resources". We might expect that agents with access to superior levels of social capital will have a relative position of power over those beneath them.

However, Lin's (2002) theory of social capital has limitations. For example, the main motivation suggested for those in higher structural positions to relate with those below, is associated with gaining access to new information or resources. It should be anticipated that gaining access to someone with better resources than your own would involve some

type of barter; valuable resources should not be given away easily. In the case of the venture capitalist, they exploit the value of their social ties to develop their portfolio. The application of social capital is expected to form part of the added value provided by venture capitalists, that their participation should (if beneficial) facilitate access to individuals with highly valued resources. Here, the investor's motivation is driven by profit, and they control the flow of resources to the entrepreneurial firm. On a superficial level this supports Lin (2002) observation of ties across structural positions. However, we emphasise that access is negotiated; only opportunities that provide financial returns will gain access to the venture capitalist resource.

Lin (2002), like Putnam (1993, 1995) also assumes a relatively static structural position of actors emphasising family history and social positions in determining structural positions. Cohen and Fields (1999) suggest a more dynamic model where an individual's access to social capital is responsive to their achievements and performance. We would expect an aspiring entrepreneur that is successful in negotiating access to an individual higher up on the social structure, will also increase their own structural position. In this way the value of the tie may provide credibility to the entrepreneur in addition to access to other resources. We see a similar influence of credibility, when important scientists or managers are recruited to a firm to attract investment at IPOs (Gulati, 2007).

If we combine the perspective of Cohen and Fields (1999) that performance has strong links with social capital, with that of Garnsey and Heffernan (2005) that social capital like other forms of capital can be accumulated, it should be expected that those with an ability to perform in business will develop relationships and accumulate ties which represent valuable social capital. The best performers would be expected to take higher structural positions with access to the most valuable resources. This view of social capital implies a rapid dynamic development of social capital where 'new comers' can arrive and thrive on the strength of their abilities. Thus the associated networks will represent the perceived importance and performance of actors operating in the entrepreneurial environment.

Lin's (2002) theory of social capital suggests the distribution of people's structural positions is skewed. People with low structural positions are in the majority, and a small minority hold access to the most valuable relational resources. We also expect from the earlier discussions that relationships within structural positions are formed more easily. It follows that in the higher structural positions the number of actors are likely to be relatively small, increasing the likelihood that actors in the highest positions will share ties

or form groups. In the entrepreneurial context it suggests that a core group of either directors or investors (and potentially a combination of both) may emerge that has important consequences for network structure.

It also follows that those with access to the most valuable resources should be targeted by those with lower structural positions. Actors in lower structural positions are anticipated to be abundant. We also expect that the number of ties per actor is greatest for those in the highest structural positions. These ideas resonate with characteristics of networks formed around hubs, where hubs are formed by a minority of actors that have access to highly valued social capital. These hubs attract connections to other actors in the network, particularly from those in lower structural positions. Therefore, the presence of hubs in the network would indicate the presence of important actors, with a centralised structure of co-ordination.

This section has shown how the distribution of social capital across a population has important implications for network structures and sub-structures. We have started to explore the organisation of networks according to the role of particular actors or groups of actors, and the implications of forming relationships within and across different groups of actors. Another literature has explored the role of groups and network structure based on the idea that relational ties have different strengths.

3.5.3 Strength of ties

Granovetter (1973) proposed that network analysis should consider ties as varying between strong or weak. Granovetter (1973 p.1360) stated that, “the strength of a tie is a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confidentiality), and the reciprocal services which characterise the tie”. Thus strong ties resulting from ties between relatives or friends, or where homophily is high, are characterised as intense, frequent, reciprocated relationships. Weak ties on the other hand are often formed between acquaintances where the frequency of contact between two agents is lower and less intense.

An important consequence of strong ties is that to some extent they are obligated. Thus strong ties are more likely to provide access to resources than weak ties. Based on the work of Granovetter (1973, 1985), Lin’s (2002) theory of social capital proposes that the strength of ties are important for the formation of relationships and access to resources. In Lin (2002) strong ties between actors represent trust and sharing of resources, as well as

“the maintenance and reinforcement of existing” resources (p.66). In Granovetter (1973) strong ties between actors represent social capital that provides access to resources of a similar nature to that of egos other ties.

An important characteristic of strong ties is that they are likely to form closed groups. For example, if strong links exist between actors A and B, and B and C, then it is very likely that a strong link will exist between A and C. The strong connection of both actors through B means it's likely that the third relationship will occur, forming a closed triad. As a consequence, information flows efficiently and freely round groups of people that have strong connections. Following Coleman, (1990, p.304) an advantage of a group, *“whose members manifest trustworthiness and place extensive trust in one another will be able to accomplish much more than a comparative group lacking that trustworthiness and trust”* (Coleman, 1990 p.304).

However, because of the closed nature of the group, each member of the group tends to share similar information or resources. For the group to access new information, it is most likely to be sourced through weak ties which connect different groups together (Granovetter, 1973). From the perspective of social capital, weaker ties, unlike strong ties, provide a breath of relationships which are un-obligated and involve dissimilar relationships. Lin (2002) proposes that weaker ties between actors facilitate access to heterogeneous resources, potentially resources of greater value (and lower value too) than one's own structural position would suggest (Lin, 2002) and so characterise ties across structural positions. However, from a social capital perspective weaker ties are predicted to be less effective in achieving actions because they lack trust and so represent weaker incentive to share resources (Lin, 2002).

The location of strong and weak ties has implications for the flow of information or knowledge through a network. Granovetter (1973) proposed that weak ties act as bridges between groupings of strong ties, such that it is mainly weak ties that connect between different groups and allow the flow of information from one social group to another. Thus in social capital theory a weak tie bridge from one social cluster provides access to resources embedded in another social cluster that would otherwise be unavailable (Lin, 2002).

3.5.4 Application to the thesis

In the venture capital-entrepreneurial firm context it is less clear which links should be strong or weak. For example, the members of a syndicate may need to work closely or share important information. In this case relationships may be characterised by significant commitment in terms of finance, time and ultimately career success, that result in intense or strong relationships. However, we also know from the literature that venture capitalists rely on a network of contacts to provide fresh information on investment, akin to weak ties. Therefore venture capitalist's networks are likely to involve a core of strong ties, supported by a wider networks based on weaker ties.

One method of identifying strong ties is to use repeated ties. Cowan et al (2007) use repeated ties between firms to represent the concept of embeddedness which is based on the ideas of social capital. When firms choose to renew a previous partnership, this is an example of relational embeddedness. If that previous partnership was successful there may be a variety of benefits from working with that partner again. For example, repeating the partnership may benefit from the previous creation of effective coordination routines or trust between the two partners. Relational embeddedness can also be used to provide reliable information about other potential partners. For example, a contact you know well may offer information on their preferred partners. When new relationships are formed on the basis of recommendations, known as structural embeddedness, the result is to create clusters in the network, which represent the accumulation of social capital between groups of actors in a network.

Our literature review highlights the variations in the strength of tie between individuals and the network structure. Strong ties between a group of venture capitalists or directors would suggest they all share the same information, effectively forming clubs of investors and directors. This would be observed as distinctive groups of repeated interactions. The alternative, where relationships are formed of weak connections would suggest a loose network without repeat interactions or identifiable patterns.

3.5.5 Summary

Our discussions in this section broadly support a networked view of venture capital and entrepreneurial firms. We find that networks have structures and sub-structures which indicate variation across different types of actors and relationships. Networks are not uniform, but contain distinctive patterns that represent structural positions of actors and different strengths of relationships between them. We have discussed theories relating to social capital and the strength of ties. We have also noted the expected relational patterns

associated with distinctive groups of actors. However, based on Chapter 2 we expect social networks to contribute to regional advantage. How do our observations in this chapter relate to the geography of networks?

3.5.6 Geographical proximity and networks

Cowan and Jonard (2008) expect that clusters found in social networks can arise from two mechanisms. Firstly that structural embeddedness creates dense ties or interconnected groups, which appear as 'localised' clusters in the network. Secondly, that the literature on geographical clusters of firms (as discussed in Chapter 2) emphasises the role of physical proximity in helping the formation of relationships between agents.

Sorenson and Stuart (2001) find in general, that the probability of forming social ties declines as the distance between partners increases. Similarly, Schutjens and Stam (2001) research on entrepreneurial networks finds that close distances enhance the value of the relationship between contacts which can be crucial in the early stages of business development. Thus adding weight to the idea that concentrations of relationships in social networks as described in both of Cowan and Jonard (2008) examples are partly the result of physical proximity between network actors.

In many ways the random and Ising networks capture aspects of our previous discussions. Ising network have been associated with Marshall's view of local geographical clusters and the production of knowledge and innovation (Cowan, 2004). In contrast the random perspective of networks has some similarity with the concept of weak ties. Weak ties involve infrequent contact and lack reciprocation. Weak ties also represent more ad-hoc ties based on loose acquaintances, but are important for the effective dissemination of information.

In geographical clusters social networks are motivated by mutually beneficial exchanges of tacit information or knowledge sharing through face to face contact (Cowan and Jonard, 2008). For example Saxenian (1996) states that the prominence of social networking and informal relationships in Silicon Valley, resulted in regional networks concerned with professional and technical expertise, rather than being tied to firm specific boundaries. The presence of regional social networks formed from a combination of strong and weak ties aided the rapid transfer of information resulting in extensive labour mobility in the region (Castilla, Hwang, Granovetter and Granovetter, 2000).

In line with our discussions of regional clustering we see that localised networks provide an important mechanism for the flow of information and knowledge in regional innovation systems. Similarly local networks involving patterns of strong and weak ties provide a trade off between developing trust based relationships within groups whilst facilitating the transfer of information across groups to provide wider regional benefits. Equally regions with networks that include important individuals with access to high quality social capital will be able to provide competitive advantages. Finally our discussion of small world structures and the role of weak ties, indicate that regional advantage can be obtained by creating links across regions to provide access to different information and resources.

However, as Cowan and Jonard (2008) note, network theories based on Marshallian clustering or social capital are less comfortable with explaining dense network pattern that occur over long distances. Gulati (2007) also notes that research involving industrial districts and the relationships within them, has not been fully explored from the network perspective. Research in these fields has often viewed the network as a property of the group of firms or the region without viewing networks as resources per se. As Gultai (2007) notes it would be useful to extend these analyses and understand the position of actors within the networks, as well as understanding the general structure. We share this view and use it to motivate an interest in understanding the role of geography in determining strong and weak patterns of relational ties.

3.6 Summary and potential applications of network theory for this research

This chapter has discussed the value of relationships and networks. In previous chapters we have focused on resources associated with the development of venture capital and entrepreneurial firms. In this chapter we have focused on a different resource known as social capital, which is defined as the value of resources associated with relationships. We have also shown how social capital is important for the development of entrepreneurial firms and the role it plays in the venture capital industry. This chapter suggests that any analysis of venture capital needs to focus on the network as an important resource, for investors, entrepreneurial firms and associated managers and directors.

In partial answer to the second thesis research question we have used our discussion of the literature on networks to develop a conceptualisation of the type of interactions present in the venture capital – entrepreneurial firm dynamic. We use this conceptualisation to structure the chapters of the thesis focusing on investor and director networks. However, we note that the literature emphasises the uneven distribution of relationships across agents

in a network. Importantly, this indicates that network structure can inform our analysis of the organisation and distribution of resources across different actors, both within and across regional contexts. Understanding actors and their relationships with others can tell us about the structure the human and social capital dynamics of an industry. In this way analysing variation between groups of actors, or actors in different locations can offer interesting comparison to the literature describing the regional dynamics of venture capital and biotechnology in Chapter 2.

Finally the techniques of social network analysis are expected to be important, together with the general emphasis of this paradigm which suggests that networks structures and sub-structures can offer insights which explain the social behaviour of individuals. The structure observed in networks has meaning, that frequent relationships represent a familiarity and strength of connection, resulting in trust and sharing resources. However infrequent or weaker ties are also useful, increasing connectivity and the flow of information across different actors. The terms 'strong' and 'weak' are relative to the context and patterns may emerge from the analysis that makes these concepts useful. In the next chapter we continue the discussion of methods for representing and analysing networks to highlight important patterns and structures.

4 Methodology

This chapter provides an overview of the approach used in the empirical thesis chapters. In this chapter we focus on justifying the choice of methods used in the thesis and explaining how they can be applied to the thesis argument. We leave the detail of particular methods applied in this research to be described in the relevant empirical chapters.

4.1 Approach

4.1.1 Thesis narrative

The approach taken by this thesis has been to build on the literature relating to hi-tech innovation, finance and regional development. We use the literature to develop the thesis research questions proposed in the introduction. The initial preparation for this research actually started with a set of very general research questions motivated by a combination of sources. These included my own personal experience in venture capital and my previous university studies in entrepreneurship, science and technology. In addition I received valuable direction from my supervision team to help focus my ideas. Finally, a range of policy literature, such as Lord Sainsbury's report into UK Biotechnology Clusters (Sainsbury, 1999), which assess national issues at a regional level, helped to shape a regional focus to the literature review.

In the first instance I constructed a set of general research questions pertinent to the study of high tech innovation, finance and regional development, to provide an initial reference point for this research. From the outset this research was intended to take a multidisciplinary approach. It has involved searching through a variety of literatures which come from different disciplines, such as finance, economics and sociology. However, the core elements of these searches were always venture capital, entrepreneurship and regional development.

As a result of these original literature searches my initial research questions centred on examining locations that support entrepreneurial firms in the UK, particularly locations that support biotechnology firms. My interest was concerned with understanding how these locations support entrepreneurial firms. This interest naturally led to an examination of these support processes at the regional level, using literature on clusters and regional innovation systems to understand the relationships between agents supporting entrepreneurship, the various agents' roles and the type of competences involved.

From these literature reviews I formed my thesis research questions. As such, my initial literature searches influenced the focus of the thesis research questions. It logically follows that each research question determines the appropriate research methods to use.

The research questions involve different levels of analysis of activity within the UK. The thesis reflects this. I use a staged approach to develop the focus of chapters. The thesis starts by examining activities in the UK in terms of activities at the regional level. This allows use to describe the variations in activity within the UK.

Progress through the empirical chapters increasingly interrogates the activities occurring within regions, looking particularly at the firms and investors and directors active within different regions of the UK. Here the purpose is to understand the detail of the regional activity, rather than just the aggregated regional level inputs and outputs.

This multi-level approach, using the region as a boundary for comparison between different UK locations, can reveal the range of activities occurring in the UK. At the most detailed level of analysis I explore the relationships between investors, board directors and firms on a region by region case basis.

The result is first to provide a comprehensive understanding of venture capital activities in the UK. I focus on the organisation of venture capital in the UK including areas of strength and weakness in terms of geography and relationship to regional resources and networks. Secondly, it is to examine the organisation of a specific sector of investment activity in comparison with the whole industry. Then to describe in detail, important processes occurring at a sub-regional level. Therefore, this thesis has the advantage of providing an analysis of activity in the UK as a sum of regional activities and also as the detail of activities occurring within regions. This mixed perspective is particularly relevant given the emphasis on regional innovation policy used by the UK Government to improve the national performance.

4.1.2 Access to data

The thesis has been developed by conducting empirical research, making use of a range of research resources. These resources include data relating to UK regions, UK firms and individuals who operate as UK firm directors. At a regional level I have accessed UK Government statistical data on various regional activities in the UK, such as education standards, commercial activity and technological activity.

At a firm level, which has also been aggregated to a regional level, I gained access to a propriety database, created by Library House. Library House is a research organisation based in the UK which monitors entrepreneurial activity in the UK. Library House, “discover, research and profile fast-growth, innovation-led private companies, their people and investors” and collect information directly from firms and their investors. Their database provides information of UK early stage venture capital investment. On average firms in the database were founded in 1999 and recorded their first round of investment in their second year. The database also provides an opportunity to obtain a reliable coverage of UK activities of 1,950 UK companies, of which 218 are classed as biopharmaceutical. I also randomly check the details of firms in the database against other newspaper and internet sources to confirm the accuracy of the data.

The strength of the Library House database is the detailed firm information it provides on SME firms, including the names of investors, and characteristics of the firm, such as technology sector. The database also provides information on the source of investment to identify public venture capital. The database covers UK investment activity between January 2000 and September 2006. The main UK office address was used to classify the location of the firm, and then summarise the data to produce regional statistics on investment activity. Finally as a number of firms featured in the database were active prior to 2000, I also have some information on firm investment prior to the 1st January 2000. Although I cannot use this additional pre-2000 information in aggregate regional statistics, this feature of the data allows me to accurately reflect firm level activity in the latter chapters of the thesis.

However, the Library House database provides a relatively short timeframe to assess the historical development of the venture capital industry in the UK. To compensate for this I used other resources such as publications from industry associations, e.g. British Venture Capital Association (BVCA), and the Biotechnology Industry Association, to provide further data on investor and firm characteristics. I use the BVCA’s annual investment survey to provide a 20 year history of investment in the UK, noting that this data only provides regional activity for the general investment activity of its members. This means I use the BVCA data to assess the general regional trends in UK investment activity.

As I also focus on analysing director activity in Chapter 9 and 10, a second data source is used to provide additional information on the directors of each firm and to check the

accuracy of the Library House data. The second database used is called FAME. The FAME database administered by Bureau Van Dyk is a database that contains information for companies registered in the UK and Ireland. FAME contains information on 3.4 million companies, 2.4 million of which are in a detailed format. FAME collects details of firm ownership and registered directors from a range of sources including statutory registrations and other propriety databases. This database can be used to obtain the details of current and previous directors of UK businesses, with information on the date directors join and leave particular board positions. To provide further detail I search a range of information sources, including the Internet and published media to provide brief biographies of the most active directors. I use information on the career history and backgrounds of SME directors to inform our analysis in Chapters 9 and 10.

A drawback of providing a very detailed analysis of UK directors, including searches on the backgrounds of individual directors, is the time required to search for information. To make our analysis of UK biopharmaceutical directors feasible, we limit our analysis of director activity to four UK regions. This means we cannot use our director data to describe activities in the UK overall. However, we select four regions as different ‘cases’ of biopharmaceutical clusters. These regions are the East, London, Yorkshire and Scotland. These four regions provide good coverage of the UK, including approximately 50% of biopharmaceutical companies active in the Library House data. This choice of regions provides a good coverage of the main UK biopharmaceutical centres, particularly around Cambridge (in the East), London and Scotland. They also cover activity in different contexts, for example, London is the UK’s capital city. The East is home to Cambridge University, one of the most important centres of biotechnology activity in the UK. Scotland is considered a UK ‘region’, however regional development policy in Scotland is decided independently from regions in England and so provides an interesting comparison region. Yorkshire has a relatively low level of biopharmaceutical SME activity and can be considered as embryonic. Finally, these cases also provide a spread of locations in the UK, which is important for considering whether ties between distant regions occur.

In addition, throughout the research process I have supplemented these predominantly secondary source resources with primary data through interviews with investors and academics researching in similar fields. This has not only complemented the statistical data on activities at the regional, firm and individual level, but also helped to tighten the focus of the empirical chapters, particularly providing additional support to examine venture capital networks. Finally during the process of developing this research there have

been opportunities to attend conferences, present working papers and have discussions with other academic researchers, public officials and industry experts. I have reviewed published academic research, company websites, promotional material, newspapers and trade magazines to provide further information for use in this research at all levels. All of these inputs also provide a useful source of material for the development of the thesis.

4.1.3 Definitions

In this thesis we negotiate two areas of research which have ambiguities regarding definitions of activity. The first is venture capital which is a term used widely to represent the financing of innovative start up companies. The second is biotechnology, which as we have described in Chapter one, is used to describe products and processes which are based utilising living organisms or tissue.

4.1.4 Considerations when researching venture capital

The term venture capital is used with a variety of meanings and is difficult to define (Martin, 1989). More recently industry analysts have suggested that venture capital is more a 'state of mind' than equity class (Library House, 2008), as turbulent market conditions result in a blurring of traditional boundaries. For example there are several activities frequently connected to the core of venture capital such as investing finance in return for equity in companies rather than providing loan finance (Florida and Kenney, 1988. Gompers and Lerner, 2001). However both loan and equity finance can form part of the same deal, as is frequently found in larger private equity deals and even small investors may use mezzanine financing involving loans to reduce investment risks⁶. Similarly in the UK we note in Chapter three that venture capital is only a minority player in the wider defined 'Private Equity Industry'.

This naturally raises the question of investment type or stage. Venture capital is frequently connected to high risk ventures because those opportunities funded are of an early development stage and unproven. The lack of history or 'track record' means they are generally considered inappropriate for traditional forms of finance which require security, such as loans (Florida and Kenney, 1998). However, the development of government and charity initiatives to encourage the commercialisation of innovation means finance sourced from tax payers is frequently positioned at the seed stage of company development, theoretically the most high risk stage. In these cases we observe finance being provided in the form of government or charity grants, loans. In some cases public money is invested as equity finance, as part of a professionally managed fund within a University or private

⁶ Information from interview with early stage investor in UK.

investor. In many respects public finance is provided as “patient capital” in the way we describe in Chapter one.

Secrecy is also a feature of all classes of private equity; venture capital is not regulated like public forms of financing, such as the stock market. There are no obligations for private equity or venture capital firms to publicly disclose the details of their investments.

Therefore, in certain cases it is not possible to determine what form of finance is being provided to a particular firm. In some cases we may only have the name of the investor, rather than any specific information on the nature of the deal, and what type of finance was received. As many investors commit to a range of equity classes and financing forms, this can make identifying venture capital difficult.

A discussion of investment types also begs the question of what is an investment?

Typically we assume an investment to represent a financial commitment, but venture capital is expected to involve active investors (Florida and Kenney, 1988). Therefore it represents an investment in terms of expertise, assistance and guidance, and ultimately investor time. However, as we have discussed in the literature review, doubts have been cast on whether venture capitalist operating in the UK perform these more ‘hands on’ tasks.

We also note that venture capital can be defined as a process, involving multiple stages as we outline in Chapter one. It starts with opportunity recognition, then an assessment of the opportunity. If a decision to invest is made, then firms are expected to grow to a stage where it may be profitable to sell to another company directly, or sell venture capitalists equity holdings on a public market. The sale or exit of an investment is a key part of the venture capitalist activities. However, we also note that the majority of investors finance firms that do not reach this stage, and in the UK recent venture capital fund performance has on average achieved a loss (BVCA, 2006).

Finally we note that a distinctive property of the venture capitalist is their position as an intermediary (Gompers and Lerner, 2001). For example, venture capitalists intermediate between the wider financial community and entrepreneurial firms. They raise finance from the financial community to create investment funds, on the expectation that they are able to increase the value of the fund and return a profit to the funds stakeholders. However, the financial intermediation role cannot be applied so clearly to investors such as angels. Angel investors, such as wealthy individuals or groups, use their own finance and invest in

businesses as they see fit. Naturally they keep any profits for themselves and tend not to act as intermediaries.

The intermediation role in venture capital can also be complicated by funds formed in conjunction with the UK Government. Public finance can be used to attract additional private finance, often on preferential terms, to create an investment fund. Finally as syndication is a frequent occurrence in venture capital deals (discussed in Chapter 8) many different investors including angels and public funds may invest together in the same firm, obscuring the distinction between venture capital and other forms of early stage investment.

In summary we find that there are a variety of investors found in entrepreneurial firms, including founders using their own capital, large investment banks and corporate firms. In practice an investment company may have a venture capital division, private equity interests and other corporate financing activities that make discerning which division provides capital to a particular firm particularly difficult. Furthermore throughout the early-stages of a firm's development, they may receive a range of different types of investment capital that further complicates the picture of venture capital financing in the UK

In this thesis we take a general view of capital committed to early stage companies as venture capital. Our focus is on entrepreneurial firms or new start-ups that seek finance in order to grow rapidly, as opposed to lifestyle firms or firms that prefer to use bank loans rather than sell equity. However, as these high-growth firms and their investors are not under additional obligations to report their activities, they are not readily identifiable for the purpose of a general survey.

In view of these difficulties in defining venture capital it is not surprising that Kaplan et al (2002) find much research on venture capital based on data obtained from external research firms. The research firms are in the business of providing data on venture capital and venture capital funded entrepreneurial firms. Many of these research companies report data on global investment activity. However, as information on deals is reliant on self reporting, Kaplan et al (2002) find that early investment rounds are often missing. As our research is focused on the UK we use the support of an external private research firm based in the UK to provide a sample of UK entrepreneurial companies that have received venture capital. In line with Kaplan et al (2002) we find that approximately 14% of deal values in

the Library House dataset were unavailable because of confidentiality issues and have not been disclosed. We check that missing values are evenly distributed across the regions.

4.1.5 Biotechnology

As McMeekin and Green (2002) note, the general definition of biotechnology given in studies in the UK is the same as we have stated in Chapter 2. However biotechnology, like venture capital, does not have neat boundaries. In fact, biotechnology can be described in terms of three generations of development. The first generation started from the use of traditional processes of the type used in beer and bread making. The second generation is based on the ‘microbiological revolution’ and the third generation is based around recent scientific advances made with regard to genetic engineering starting in the 1970s (ibid). The authors note it is often this final technology wave that is taken to mean biotechnology. However, in both the second and third generations we also find reference to the application of the technology for pharmaceutical products (ibid).

For the purpose of this thesis, we need to understand biotechnology with reference to entrepreneurial firms. We note the Walsh et al (1995) refer to biotechnology firms as those started after 1975 which are typically small and spun out from publicly funded research, particularly in molecular biology. Brink, McKelvey and Smith (2005) include a variety of definitions for biotechnology, noting that the diffusion of the technology has resulted in its application across a range of industries and sectors.

As biotechnology is not defined as industry this makes identifying firms difficult, and we cannot expect to determine a definitive list of UK biotechnology firms. Our motivation is to understand the development of a sub-set of firms operating in the healthcare and pharmaceutical industry. As we look at entrepreneurial, new start-up firms in this area, by definition they will include biotechnology firms developing products and processes applicable to the Pharmaceutical industry. Our definition of biotechnology includes start up biotechnology and pharmaceutical firms (referred to as biopharmaceutical from now on). We exclude other types of firm in the healthcare industry, such as medical devices, where these represent purely mechanical innovations.

To help define this group of firms, we use the International Classification Benchmark (ICB) to identify firms according to their main source of business revenues. We select firms classified as Pharmaceutical and Biotechnology. In addition, we also use Library House’s own classification, based on self reported activity, to select firms operating in

pharmaceuticals and drug development. This adds a small number of software development firms active in R&D in the pharmaceutical industry to our biopharmaceutical dataset. Importantly this definition of biopharmaceutical firms excludes chemical suppliers or medical devices/technology firms. Therefore it is a group of firms with direct relevance to the pharmaceutical industry.

In several chapters we compare the activity of investors or firms active in biopharmaceuticals to other sectors. We define these sectors in broad terms using the ICB definitions. This creates categories of, Communications (Comms), Information Technology (IT), Healthcare (HC) and Other. The Healthcare sector naturally excludes biopharmaceuticals. The sector labelled as Other includes activities related to media and financial services.

4.1.6 Methods

We employ several different approaches to the development of the thesis. Our first research question asks what factors determine regional investment in the UK. This is a ‘what’ type question, which at its most basic level is a descriptive question concerning a list of factors which are important in determining regional investment activity. In part answer to this question, we generate a list of factors from the literature. However, to fully answer this question, it implies we consider ‘how’ these factors influence investment, in order to be sure that we do not consider relatively unimportant factors. We can also take this further by considering, ‘what if’, for example we increased the activity level of one type of factor. What would happen to the investment activity? By examining these ‘how’ and ‘what if’ type questions, we can help to clarify our answer to the main question.

In Chapters 5 and 6 we answer the first group of questions by developing a model of the operation of venture capital derived from the literature. We use the factors expected to be important in influencing venture capital investment to guide our data collection. Then, using this data, we can test to see if our expectations regarding the influence of the theoretical factors are found. The combination of collecting non-experimental data, based on a theoretical model, and then using the data to test the model, is at the heart of an econometric approach (Wooldridge, 2003). In this approach, we use statistical analysis (regression) to evaluate how well our model performs overall. We also consider the influence of each factor or variable included in the model, on the dependent variable.

We use econometrics in our thesis to answer the first research question. We look at how regional resources can be related to the overall level of investment in a region. Secondly we use a similar model to compare regional resources to investment activity in different sectors.

We also use econometrics in Chapter 8 to provide a partial answer to the second thesis research question. We build a model to investigate the different factors that motivate investors to finance the same firms. In this way, we use econometrics to understand how factors, such as location and amount of investment in a firm, determine the size of participation of different investors. The analysis of factors that drive the syndication of investors (i.e. to finance the same firm) provides the starting point for our analysis of relationships found in venture capital. The syndicates act as the building blocks for a network of investors tied to the same investments.

There are a variety of econometric techniques and methods applicable to different dataset and circumstances (Wooldridge, 2003. Kennedy, 2000). In this thesis our techniques are defined by our datasets. We use a panel data regression (Baltagi 2005) and count data models (Scott Long, 1999). We use specialist software to perform the regression analysis (STATA and EViews).

To complement this statistical approach we also examine the second thesis research question using an exploratory social network analysis. The analysis of relational data using social network analysis has received contributions from many fields including anthropology, psychology and mathematics, emerging as a field in the 1960/70s (Scott, 2000, p.7). Early contributions were made from psychology, based around sociometry. This work focused on the analysis of patterns of thought and perception, and used the sociograph as a tool for representing actors (using points) and relationships (using lines). This has resulted in a 'sociometric' tradition of analysis patterns in the structure of networks, with the assumption that the individual components of network patterns would have different properties from the overall network.

More recently these sub-groups have been termed cliques, clusters and blocks. Ultimately, the decomposition of networks into sub groups could potentially indicate important structural features (Scott, 2000 p.10). Where "the social structure according to Nadel, is an overall systems network or patterns of relations (1957, p.12), which the analyst abstracts from the concretely observable actions of individuals. By 'network' he meant 'the

interlocking of relationships whereby the interactions implicit in one determine those occurring in others” (Scott, 2000, p.30)

Similarly from an applied perspective De Nooy et al (2005) suggest that “the main goal of social network analysis is detecting and interpreting patterns of social ties among actors” (p.5). It is also important to observe the absence of connections, such as structural holes, where few ties are found. Furthermore,

“the structure of relations among actors and the location of individual actors in the network have important behavioural, perceptual and attitudinal consequences both for the individual units and for the system as a whole” (Knoke and Kuklinski, p.12 1982).

Although, in network analysis it is rarely possible to analyse the total network of relationships given the multitude of types of linkages within and between communities and organisations. The usual approach is to analyse a reduced number of aspects of the total network, known as a partial network (Mitchell, 1969, cited Scott, 2000, p.30). The partial network can be based around an individual and their relationships, known as ego-centred networks, or an abstraction of the overall network such as, *“a particular aspect of social activity: political ties, kinship obligations, and friendship or work relations”*. (Scott, 2000, p.31)

The social network approach is particularly useful for interpreting individual actors in a network of relationships with other actors. As we have noted in Chapter 3, the network concept is frequently applied to the venture capital – entrepreneurial context. In Chapters 7 and 9 we examine the network literature relevant to our research question to develop a number of expectations regarding the structure of networks in the UK. We use social network analysis, and social network tools, such as software called Pajek, to represent these networks and describe their properties.

There are complex statistical methods for analysing networks. These techniques are more complex than traditional statistics, as the concept of independent units of analysis used in traditional statistics, is not appropriate when actors are inter-related (Wasserman and Faust, 1994). There are relatively few studies of either investor, or director networks in biotechnology, and fewer still on UK regional networks. Therefore, instead of developing a statistical model we adopt an approach based on descriptive network statistics and manipulation of visual network representations, or sociograms, to examine the networks.

Sociograms are used in Chapters 7 and 9 to show the structure of networks involved in venture capital syndicates and relationships between directors. The sociogram represents both the individual actor (as a node) and the ties between actors (as a line). The sociogram is a graphical representation of the network data, which can be used to qualitatively assess the network structures and sub-structures we have discussed in Chapter 3, as well as support any statistics describing the various networks.

In network analysis involving two modes, in our case using either investors and firms or directors and firms, there are two possible general network representations. The first is to include all modes in the representation of the network, a mode 2 representation. In the mode 2 network we see that firms are linked through having common investors or directors, as it is the investors and directors rather than the firms, that co-ordinate the network.

In the alternative, mode 1 representation, we can choose to effectively 'hide' one of the modes, and represent the connections between the remaining mode directly. Therefore we would choose to remove the firms from our network, such that the relationships between investors are shown to appear directly connected. A line is drawn whenever two investors are affiliated to the same firm.

This transformation of a mode 2 network to a mode 1 representation results in some loss of information regarding the firms involved. However, generally the mode 1 representation is the standard form used to represent networks and can be analysed with standard techniques (De Nooy et al, 2005). It also simplifies the visual inspection of the network structure to the particular mode of interest. When interpreting networks transformed into 1 mode networks the lines between vertices (or nodes) may represent more than one common affiliation (line multiplicity). The value of these lines relates to the number of common affiliations between the two joined vertices.

As we also want to evaluate the role of individuals in network sub-structures and regional dynamics an advantage of the descriptive sociometric approach is that we can explore the network without restricting our findings to a pre-determined model. We use the literature to generate expectations, which guide our analysis. However, as in qualitative analysis used in social theory construction, (such as grounded theorising) we remain open to other characteristics and observations of the network structure. This means that in the process of investigating our expectations, we refine our methodological approach, tailoring it to our observations.

Finally throughout the research thesis we also make use of a variety of qualitative data. This includes data collected from primary and secondary source to help situate the research in the field of venture capital and generate our research questions in the first instance. The use of qualitative data adds further interpretation to the results of the analysis based on quantitative data. And perhaps most importantly we use qualitative data as an additional source of data to 'sense check' or triangulate our overall thesis findings.

For example we use data from interviews with investors to check our findings in Chapters 5 and 6. We also use interviews with academics and investors to justify our decision to examine networks in venture capital. Finally we use a range of qualitative data to support our analysis of the relationships between investors and directors in Chapter 9 and 10.

The process of research involves making choices regarding the type of analysis performed and ultimately how to structure the empirical work. As part of this process, alternative versions of the thesis are considered. The final result represents the best possible thesis design, given the resources and time available. However, one alternative thesis structure considered would have been to examine activity in the UK at only the regional level or at the detailed level within regions.

For example, one option for the thesis would have been to perform a more detailed econometric analysis of biotechnology investment activity, perhaps at the city or county data level. This would provide a more fine grained analysis. However, one persistent issue in this research has been to locate consistent data series on regional activities across both regions and sectors with time.

In this thesis we make best use of the data available to study the dynamics of relationships between regional resources and financial investment. Many of the measures used in the econometric analysis of specific sectors are available for short periods and do not cover all UK regions. Rather than attempt to collect data through a survey instrument, we make use of the strength of our data. For example surveys typically receive low response rates and are therefore subject to a variety of biases (Sapsford, 1999) and would be unlikely to yield improved time series data.

The strength of the data used in the thesis is that it provides information on each investment deal and the firms involved. This makes it possible to examine activities within

regions as well as aggregating the data across regions. As we move through each chapter we progress towards a more detailed sub-regional analysis and concentrate on the activities of the biopharmaceutical sector only.

4.1.7 Summary

In this thesis we have combined a variety of approaches, using different data sources to provide a more complete understanding of the dynamics of UK Venture Capital investment. We work with the limitations of the data and the available literature, and use a range of methods to support our findings. The mixed method approach employed in the empirical chapters enables the research to present a comprehensive assessment of UK venture capital activity, and therefore strengthens the thesis conclusions.

4.2 Ethics

It is the researcher's responsibility to design the research to ensure integrity and quality without causing harm to others. Therefore this research has been conducted in line with the British Sociological Association statement of ethical practice and in accordance with the six key principles of ESRC's research ethics framework⁷.

As this thesis uses the names of particular investors and directors in reference to their activities, care has been taken to use these materials in a way that is sensitive to businesses and the individuals involved. Therefore we do not speculate or provide personal comment on individuals or firm performance. However, where published material is available we may refer to this in the thesis text. This includes published details of investments firms have made and their reported outcomes. This type of material is publicly available, for example directors of companies in the UK are required to notify Companies House of their directorship positions. Although we make every effort to insure the information we present is correct, we do not report the full directorship history of any individual, as we only provide information relating to activities connected to our firm sample. Our use of this material is in accordance with other published academic works, who have presented detailed information on director's activities.

Finally, although no interview material is quoted directly in this thesis; several interviews with investors were used to inform the direction of the thesis. Where consent was given these interviews were recorded and transcribed, and a full transcript made available for each participant. To conform to ESRC requirements, transcripts and interview hard copies are kept only in the confidential file system at the ESRC Innogen Centre.

⁷ http://www.esrc.ac.uk/ESRCInfoCentre/Images/ESRC_Re_Ethics_Frame_tcm6-11291.pdf

5 Geography of venture capital

5.1 Introduction

In this chapter we begin our analysis of the distribution of venture capital investment in the UK. The aim of this chapter is closely related to the first thesis research question. In this chapter we examine the factors that determine the distribution of venture capital investment in the UK and also investigate whether these factors are similar across regions.

The literature review in Chapter 2 has outlined the rise of venture capital finance over time. However, the development of venture capital has been characterised by a distinctive skew towards certain regions. In line with the literature on regional concentrations of venture capital activity we examine factors that may influence the supply and demand of investment. These include demand factors such as the number of entrepreneurial opportunities (Martin et al, 2002), the level of technology expertise (Florida and Kenney, 1988; Florida and Smith, 1993), the presence of professional expertise and business infrastructure (Mason and Harrison, 2002). On the supply side, factors include the concentration of financial activity (Mason and Harrison, 2002) and the location of venture capitalists (Powell et al, 2002). Finally network activity is associated with both supply and demand (Florida and Smith, 1993; Martin et al, 2005).

Drawing on the literature reviewed in Chapter 2, this chapter develops an empirical model based upon the factors that are expected to influence the supply or demand for venture capital. Next we provide descriptive statistics on the regional distribution of venture capital in the UK, before describing the dataset, the econometric model and the results.

5.1.1 Supply and demand

The level of demand for venture capital increases with the level of entrepreneurial activity. Entrepreneurs starting and running businesses demand finance to grow and develop their businesses. In the UK the greater demand for venture capital in the South East is suggested to be a result of the greater demand for risk capital for new and expanding business (Martin, 1989). Similarly, in the US, Florida and Smith (1993) show that regions with concentrations of high-tech start ups will demand greater levels of investment.

Regions with higher concentrations of professional expertise are able to provide better quality business environments and support, in terms sources of skilled labour, advice and a general infrastructure that provide inputs into the development of business. These might include factors such as sources of trained management staff or consultancies with an

appreciation of how to organise a business to receive venture funding. Professional expertise can assist in the development of more viable investment opportunities directly by helping the management team or filling competence gaps. They may also provide services to help with the creation of appropriate strategies and business plans. In this way professional expertise can help entrepreneurial businesses become 'investor ready' (Mason and Harrison, 2001).

The demand for venture capital investment also increases with the concentration of technology activity. Technology centres have been historically associated with the development of the venture capital industry (Florida and Kenney, 1988). In particular Florida and Smith (1993) found that the level of R&D activity positively influenced venture capital investment. This type of activity creates investment opportunities through the development of new technologies and technology business which generally have high financial capital requirements. Therefore a region with a high concentration of technology expertise is likely to provide a source of technological capability with potential for exploitation through venture capital investment.

Mason and Harrison (1992) and Martin et al (2005) have also observed that supply and demand side factors interact, where "experience and knowledge of the local venture capital market spread through local business and information networks encourage additional entrepreneurial activity to seek private equity" (Martin et al, 2005 p.1214). Thus networks, formed of venture capitalists, entrepreneurs and small firm directors can be seen as a mechanism for stimulating supply and demand for venture capital investment. In particular Oahey (2003) notes that some UK SME owners are either unprepared or unconvinced about using venture capital to grow their businesses. Regional networks involving business angels or lawyers can help to educate would-be entrepreneurs, acting as dealmakers that can convert raw opportunity with the potential for commercial exploitation, into start-up businesses which are capable of seeking venture capital funding by providing advice and guidance (Mason and Harrison, 2002; Suchman, 2000). In this way regional network activity can influence the level of demand for venture capital.

Florida and Smith (1993) found that areas with highly connected local venture capitalists will increase both the supply and the demand for venture capital investment. They collect network effects into a single variable measuring co-investment, to understand the influence of network activity on supply, in the form of VC offices, and demand, in terms of investment received. A venture capitalist with a high level of investment connectivity is

likely to increase the supply of venture capital available for investment in the region through syndication with other investors based in other regions. Similarly, by increasing connectivity with other regional financial centres they are also able to raise larger funds. This type of effect might be expected from highly connected venture capitalists. Echoing Mason and Harrison (2002), it follows from our previous discussion of networks that the positive influence of well connected investors on the supply of capital will simultaneously increase activities which promote demand for venture capital. For example, increased network activity between would-be entrepreneurs, investors and their associates, involving the discussion of opportunities and information sharing, will help to overcome the type of barriers to approaching venture capitalists described by Oakey (2003), stimulating further demand for venture capital.

Other factors influencing the supply of venture capital in a region are the presence of venture capital offices and the concentration of financial activity. The presence of local venture capital offices is linked to high levels of local investment and may be explained by the need for venture capitalists to closely monitor the progress of their investments (Powell et al, 2002). However, Florida and Smith (1993) found a negative relationship between the venture capital office location and the level of regional funding. The authors explained the result as in part due to network syndication reducing the importance of access to local venture capital. They also explain the result as due to data based on administrative geographical data boundaries which cut through clusters of hi-tech investment and so artificially increase the export of funding from key regions. As the Florida and Smith paper uses the number of deals, rather than the capital invested, we can improve on their study, by using both activity measures.

An important factor expected to influence supply is the regional concentration of financial activity, as this provides a potential source of funding for VC's. However VC office location and financial activity have been shown to positively correlated (Florida and Smith, 1993); particularly in the UK where it has been shown that the location of venture capitalists is strongly related to the concentration of financial activity in that region (Mason and Harrison, 2002). Therefore we expect the concentration of financial activity to strongly influence the supply of capital and also capture secondary effects such as the location of VC offices.

5.1.2 Interactions effects

There are complex interactions between these supply and demand factors that influence historical patterns of investment. The concentration of investment in a particular region has a tendency to increase future investments in the same area, whilst reducing the available investment for other regions, suggesting that there may be lagged effects of the dependent variable, and therefore dynamic interactions. In this sense venture capital may be 'learned process' whereby the activities involved in venture capital investing are built on year on year (Martin et al, 2005).

We might also expect there to be an endogenous relationship between venture capital and entrepreneurship. It was proposed earlier that venture capital is dependent upon the level of entrepreneurship; however it is also conceivable that the likelihood of starting a business is related to the availability of venture capital finance. For example the accumulation of venture capital in a region may help stimulate an entrepreneurial culture, creating the perception of winner regions, increasing the level of business formation (Martin et al, 2005). From a Knightian entrepreneurial perspective the availability of venture capital may create opportunities for a would-be entrepreneur, by reducing funding constraints or increasing access to profit making opportunities versus paid employment.

To some degree there may be interactions between the factors we have described. For example, business located near financial centres, and so likely to be near VC offices, may benefit from a greater supply of venture capital because of the result of opportunity costs of proximity, or the circulation of information through local networks. Clusters of financial activity may also indirectly offer a more plentiful supply of professional expertise, and business support. These are also factors suggested in section 5.1.1 as being linked with demand for venture capital. Overtime these interactions may reinforce or increase differences between regional processes related to venture capital investment in the UK. Therefore, such patterns may explain the persistence of regions with low levels of venture capital investment. We expect that some of these interactions would be captured by measuring networking activity in regions. However, some of the regional processes are also likely to represent distinctive regional characteristics resulting from historical or geographical factors which are not captured by measuring individual factors.

5.2 Model

Following the previous theoretical discussion, the remainder of this chapter specifically examines the relationship of venture capital to regional level variables describing the shares of entrepreneurial activity, financial capability, technological capability and

professional capability level in the population. In this section we build a model to explain the regional distribution of venture capital. To do this we adapt a model from Jeng and Wells (2000) which was used to investigate differences in the variations of venture capital investment between nations. We use a similar method to Jeng and Wells (2000), but change the variables used in the model to reflect factors that influence UK regional activity. A reduced form equation is derived from the following (1) demand, (2) supply and (3) equilibrium equations for venture capital activity (VC_{it}), indexed for each region, i and year, t .

$$(1) \quad VC(d)_{it} = \beta_1 + \beta_2 Ent_{it} + \beta_3 Deg_{it} + \beta_4 Pat_{it} + \beta_5 Net_{it}$$

$$(2) \quad VC(s)_{it} = \alpha_1 + \alpha_2 FS_{it} + \alpha_3 Net_{it} + \alpha_4 VC_{it-1}$$

$$(3) \quad VC(d)_{it} = VC(s)_{it}$$

The independent variables are entrepreneurship (Ent_{it}), financial capability (FS_{it}), professional capability (Deg_{it}), technological capability (Pat_{it}), networks (Net_{it}). A variable for lagged venture capital activity (VC_{it-1}) is also suggested from the previous discussions to help explain historical investment. A full description of how these variables are measured and descriptive statistics are included in the data section of this chapter.

The independent variables in equation (1) and (2) are expected to have a positive influence on the corresponding dependent variable. Assuming the above are linear equations, they can be equated for the equilibrium equation, and the supply equation can be solved for Net and substituted in the demand equation. This reduced form equation gives the level of venture capital activity:

$$(4) \quad VC_{it}(\theta) = \pi_1 + \pi_2 Ent_{it} + \pi_3 Deg_{it} + \pi_4 Pat_{it} + \pi_5 FS_{it} + \pi_6 VC_{it-1}$$

Where :

$$\pi_1 = \frac{\beta_1 \alpha_3 - \beta_5 \alpha_1}{\alpha_3 - \beta_5} \quad \pi_2 = \frac{\beta_2 \alpha_3}{\alpha_3 - \beta_5} \quad \pi_3 = \frac{\beta_3 \alpha_3}{\alpha_3 - \beta_5} \quad \pi_4 = \frac{\beta_4 \alpha_3}{\alpha_3 - \beta_5} \quad \pi_5 = \frac{-\beta_5 \alpha_2}{\alpha_3 - \beta_5} \quad \pi_6 = \frac{-\beta_5 \alpha_4}{\alpha_3 - \beta_5}$$

Following Kennedy (2003) the π_i coefficients in the reduced form equation can be interpreted as the long term multipliers of the right hand side variables in equation 4. These reduced form coefficients can be used to predict the level of venture capital activity when supply and demand are in equilibrium. However, as each reduced form coefficient is effectively scaled by network effects (α_3 and β_5); they do not tell us the value of the coefficients in the structural form or supply and demand equations.

In order to identify the supply and demand equation coefficients we need to make some restrictions on the values of the coefficients. It follows that if we expect the structural

coefficients (β_1, \dots, β_5 and $\alpha_1, \dots, \alpha_4$) to have a positive value, then our reduced form equation suggests that the signs of the coefficients π_5 and π_6 are expected to be the opposite of π_2, π_3 , and π_4 . It also follows that the actual signs of the π_i coefficients are also affected by the relative magnitudes of $(\alpha_3 - \beta_5)$, the coefficients of the influence of networking on the supply and demand equation. For example, in the case where, $\alpha_3 > \beta_5$, the influence of networks is greater on the supply, rather than the demand for finance. Then given our previous assumptions, our expectation is that π_2, π_3 , and π_4 would be positive, and π_5 and π_6 negative.

We summarise our expectations in the table below. Table 5.1 shows our expectations regarding the influence of the variables in our model on investment activity. Based on the theoretical discussion in this chapter, the table shows the prediction for the relationships of each variable in the model with respect to the regional level of investment. The table also shows the expected direction of influence of each independent variable in the structural equations. We also show how our expectations for the influence of each factor translate into the reduced form model, where the outcome also depends on the scaling by the coefficients of *Net* ($\alpha_3 - \beta_5$).

Table 5.1 Theoretical predictions of the influence of supply and demand variables

Structural form variables	Influence on:	Direction of influence in structural form	Direction of influence in reduced form*	
			If $\alpha_3 > \beta_5$	If $\alpha_3 < \beta_5$
Ent	VC(d)	+ve	+ve	-ve
Deg	VC(d)	+ve	+ve	-ve
Pat	VC(d)	+ve	+ve	-ve
Fs	VC(s)	+ve	-ve	+ve
VC _{t-1}	VC(s)	+ve	-ve	+ve
Net	VC(s)	+ve	N/A	N/A

*Assuming *Net* has positive influence on supply and demand equations, otherwise predictions for reduced form do not hold

In order to recover the value of the coefficients in the structural form, we would need to make additional restrictions which impose particular values of the network coefficient, α_3 and β_5 . A restriction can be based on additional information from theory or other research. Our search of the literature does not provide suggested values for these coefficients. In Chapters 7, 8 and 9 we examine networks in more detail to support our analysis and expectations.

5.3 Issues in estimation

In this section we consider how to apply econometric techniques to provide estimates of the reduced form coefficients described in equation 4. A large variety of econometric methods are used in the literature. However, we specifically want to understand the factors

that have influenced the evolution of distribution of venture capital across UK regions. This implies that we need to model regional activity over time. To do this we need to use panel estimation techniques.

An important property of panel regression techniques is the opportunity to control for unobserved heterogeneity with time or across regions (Kennedy, 2003). For example, key characteristics of each UK region may not be captured in the variables we outline in our model. It is important to understand specific regional or period effects that explain venture capital investment. There are a variety of historical or geographical factors that can be controlled for, such as the local awareness or acceptance of venture capital as a method of finance, the distance from the capital city, or period specific effects such as changes in the UK stock market, which are not accounted for by the independent variables.

To control for these unobserved types of effects we can use random or fixed effects panel regression. In the fixed effect regression a dummy variable is added to the model for each region. This new variable acts as a regional intercept or constant. It controls for the fact that each region may have different natural starting point or base level in the model. A drawback of the fixed effect estimator is that we can only include variables in the model that change with time, because of the estimation procedure. This means any regional variables that are fixed with time are captured by the intercept for each region, reducing the opportunity to include time invariant regional characteristics in the regression model.

The alternative method for controlling for regional heterogeneity is the random effects estimator. This estimator has a similar interpretation, but computes the regional heterogeneity as part of the model's error term, and allows for static regional variables. A drawback of the random effects approach is that if the regional intercepts are correlated with the explanatory variables (i.e. regions with higher levels of activity have high intercepts) this creates bias in our coefficient results (Kennedy, 2003).

To test for the presence of correlation between the regional intercepts and the explanatory variables we use a Hausman test from the EViews panel regression routine. The Hausman test checks whether the differences between the random and fixed effect estimates are significant. A statistically significant difference between the two result sets indicates the presence of bias in the random effects estimations.

The Hausman test indicated that fixed effects estimation were preferred for the models used in this chapter. The test rejected the null of no significant difference between random and fixed effects for regional dummy variables and period dummy variables. This indicates that using the random effects model would create bias in the estimation of our model coefficients, owing to correlation between the composite error and explanatory variables.

To check that fixed effect estimation is appropriate we also use a redundancy test. This test checks whether the results of the fixed effects regressions are statistically different from a simple panel regression, where only one intercept is specified. The test rejected the redundancy of fixed effects. Therefore we use the fixed effects estimator in our regression procedure.

Our estimation routine is as follows. First we run a simple panel ordinary least squares (OLS) regression to provide a basis upon which to compare the more sophisticated regression techniques. Second we estimate our model using cross section fixed effects to control for unobserved regional heterogeneity. Third we estimate the model with both regional and period effects, to control for unobserved effects which change with time. Forth we estimate the model with only period effects. Finally we estimate a cross section fixed effects model with unrestricted coefficients. In this last model the coefficients (β_i) are calculated for each region. This model is included to test for the presence of heterogeneity across different regions in the relationships between the independent variables and venture capital. In the results section we report the fifth model separately from models one to four.

The full estimation model is shown below including the relevant effects. We also include the general error term, u_{it} and random effects error term γ_{it} . The estimation sequence is as follows:

- I Panel least squares (pooled)

$$vc_{it} = \alpha + \beta_1 ent_{it} + \beta_2 fs_{it} + \beta_3 deg_{it} + \beta_4 pat_{it} + u_{it}$$
- II Panel least squares with cross section fixed effects

$$vc_{it} = \alpha_i + \beta_1 ent_{it} + \beta_2 fs_{it} + \beta_3 deg_{it} + \beta_4 pat_{it} + u_{it}$$
- III Panel least squares with cross section and period fixed effects

$$vc_{it} = \alpha_i + \beta_1 ent_{it} + \beta_2 fs_{it} + \beta_3 deg_{it} + \beta_4 pat_{it} + \gamma_i + u_{it}$$
- IV Panel least squares with period effects only

$$vc_{it} = \alpha + \beta_1 ent_{it} + \beta_2 fs_{it} + \beta_3 deg_{it} + \beta_4 pat_{it} + \gamma_i + u_{it}$$
- V Unrestricted panel least squares with cross section fixed effects

$$vc_{it} = \alpha_i + \beta_{i1} ent_{it} + \beta_{i2} fs_{it} + \beta_{i3} deg_{it} + \beta_{i4} pat_{it} + u_{it}$$

Our theoretical discussion suggested evidence for incorporating the lagged effects of venture capital on future values investment supply. However, it is not appropriate to include lagged variables in the fixed effects model. Baltagi (2005) has shown that including lagged variables in fixed effect panel regression will produce bias in the value of the coefficients produced in the order of $1/T$ (Baltagi, 2005, p.135). As our previous discussion indicates the presence of regional heterogeneity, it is important to use the fixed effects estimator. Therefore, our estimations will use a static model, without lagged variables. We control for the effects of serial correlation and heteroskedasticity using White error correction.

In section 5.1.2 we noted the possibility of entrepreneurship having an endogenous relationship with the dependent variable. If an endogenous variable is included as an explanatory variable and is correlated with the error term it can cause bias in the coefficient estimates. For example, if entrepreneurship is endogenous, then changes in the level of investment influence entrepreneurial activity. In the model a change in the error term influences investment, but it will also simultaneously affect entrepreneurial activity. As entrepreneurial activity is expected to be independent to any other activity, we obtain bias in the OLS coefficients produced (Kennedy, 2003). To check for the presence of endogeneity in the estimations we use another Hausman type test. The test rejects the presence of endogeneity in our estimations⁸.

5.4 Data

5.4.1 Dependent variable

We showed in Chapter 2, that UK venture capital industry has developed differently from the industry in America. In this chapter, the term venture capital will refer to a wide definition of activities, including, start-up/early stage finance, development/expansion capital and MBO/MBI. We also provide two alternative measures of venture capital recorded by year of investment. Firstly the investment amount, VC(amount) and secondly the count of the number of investments, VC(count).

The count of investment is preferred measure of investment activity. The presence of one-off large value MBO/MBI deals can strongly impact the regional VC (amount) data. In such as case a single deal may reflect a random regional shock rather than reflecting underlying regional processes.

⁸ Thus it is assumed the estimations will be unbiased and consistent, but not efficient. The lack of efficiency is controlled for by using error correction.

During the period analysed the venture capital industry experienced rapid growth. Our aim is to understand the factors which influence the regional distribution of investment, rather than model the growth of the industry. Therefore exponential growth in investment may distort our analysis. To control for this we express the dependent variables in the form of regional shares of activity.

The data for the dependent variable was obtained from the British Venture Capital Association (BVCA, 2003) annual report on investment activity, collected from its members each year. The report provides one of the most commonly used source of historical data on venture capital activity in the UK. Although the BVCA data is membership based, it includes the active of the majority of investors operating in the UK. On weakness of the data is that the membership of the BVCA is optional. Therefore the coverage of the earliest periods in the BVCA data is weakest. We will assume that errors included in this series are the result of random processes.

5.4.1.1 Imposing regional boundaries

In order to evaluate our regional model we must impose regional boundaries on UK investment activity. The data described above forms a panel dataset for the years from 1984 to 2003 (1984 partially estimated from national totals), for nine regions of the UK. The choice of regional boundaries were determined by the venture capital series which are based on the Government Offices regions (GOR), which are reported in two time series, one prior to the reorganisation of the GOR (1985-1997) and one after (1998-2003). During this re-organisation several counties were moved between the North East and North West, and between the South East and East. Additionally, London is not included as an individual region prior to 1998.

In order to develop a continuous series for the period 1984-2003⁹ some GOR regions were merged. The result is nine regions are used in the estimation. These regions include, Southern (South East including London and Eastern region combined), Northern (North East and West), South West, Yorkshire and Humber, East Midlands, West Midlands, Scotland, Wales, and Northern Ireland. One positive impact of merging regions in the South is to minimise the effects of spatial correlation. For example it has been suggested that the South East and East have shown a high proportion of funding originating from London (Martin, 1989).

⁹ Data for 1984 is provided from estimates

5.4.2 Independent variables

Table 5.2 below describes the data used to measure the variables described in the reduced form equation (4). The independent variables, *Ent*, *Fs*, *Deg*, *Pat* are included as ratios to standardise for the different geographical sizes of regions. This also helps to reduce the potential for spurious regression arising from factors such as background population growth. Due to the absence of available data, no panel dataseries are available to measure the location of venture capital offices, although we note in section 5.1.1 that office location is expected to be correlated with the concentration of financial services (*Fs*). In the absence of a dataset on R&D activity for the period 1984-2003, a panel dataseries on patent activity (*Pat*) is used as substitute. Similarly data for the levels of public investment in venture capital funds was not available for the period analysed.

5.4.2.1 Data sources

As shown in Table 5.2, data for the independent variables was obtained from the UK Office of National Statistics (ONS) Regional Trends publications (No.s 20-38) and NOMIS database (official labour market statistics). Additional statistics were obtained from the European statistics agency EUROSTAT online. The *Epapps* series does not contain values for Scotland and further searches of data did not provide an adequate series. As a result the final panel data set includes eight UK regions with time series from 1984-2003.

Table 5.2 Description of data and variables used in chapter

Series	Calculation*	Description
VC	PE_{it}/PE_t for	Share of amount/number of investments
Ent	$NVAT_{it}/Civ_{it}$	Number of new VAT registrations per civilian labour population
Fs	$FSemp_{it}/Emp_{it}$	Number of financial services employees per employee population
Deg	$Prof_{it}/Workage_{it}$	Number of degree qualified people per working age population
Pat	$EPAPPS_{it}/Civ_{it}$	Number of patent applications per civilian labour force
Data	Data source	Description
PE	BVCA annual survey	Count of/Amount of Private equity investment
NVAT	ONS NOMIS database	New Value Added Tax (VAT) registrations
FSemp	ONS Regional Trends	Employees in working the financial services
Prof	ONS Regional Trends	Number of people of working age with degree level qualification or above
EPAPPS	EUROSTAT database	European patent applications recorded by priority year
Civ	ONS Regional Trends	Civilian Labour force
Emp	ONS Regional Trends	Number of employees
Workage	ONS Regional Trends	Number of working age population

* i regions = $\{1,...,N\}$ t years= $\{1,...,T\}$

5.4.3 Empirical analysis

5.4.3.1 Descriptive statistics

Table 5.3 below shows the descriptive statistics of the data set. A balanced panel was used with each variable containing 160 observations, of regions (N) = 8 and periods (T) = 20. The statistics for the alternate dependent variable show some differences. The share of venture capital in each region show greater variation when the ‘amount’ of investment is used, showing a lower minimum and higher maximum and greater standard deviation. A comparison of the time series graphs of the two variables shows that although a similar trend in fluctuations is found, the shares by count follow a less exaggerated trend.

All series have distributions that reject a Jaque-Bera null hypothesis of normality¹⁰, suggesting that the regional data collected reflects distinctive regional variances. The patent data shows a particularly strong presence of kurtosis and skewness, indicating a concentration of the data around the mean score and a distribution with an extended tail. This is because most regions have a relatively similar *Pat* score. Even after controlling for the size of the labour force the main outlier in the *Pat* series is the Southern region, resulting in a skewed distribution.

Table 5.3 Descriptive statistics of chapter dataset

	VC (amount)	VC (count)	Ent	Fs	Deg	Pat
Mean	0.116	0.111	0.006	0.116	0.105	0.021
Median	0.059	0.063	0.006	0.106	0.107	0.014
Maximum	0.695	0.587	0.011	0.265	0.208	0.147
Minimum	0.000	0.003	0.005	0.055	0.056	0.001
Std. Dev.	0.172	0.140	0.001	0.045	0.032	0.023
Skewness	2.196	2.176	1.074	1.140	0.689	2.982
Kurtosis	6.511	6.369	3.810	4.473	3.439	14.036
Jarque-Bera	210.763	201.959	35.150	49.137	13.957	1048.981
Probability	0.000	0.000	0.000	0.000	0.001	0.000
Sum	18.604	17.786	1.019	18.529	16.839	3.321
Sum Sq. Dev.	4.704	3.112	3.39x10 ⁻⁴	0.321	0.160	0.083
Observations	160	160	160	160	160	160

The correlation analysis in Table 5.4 shows an association between the alternative dependent variables and the independent variables. Overall we find our independent

¹⁰ The central limit theorem proposes that when dependent variables are non-normal the sample characteristics of the estimate produced from OLS regression are still normal, so OLS is still appropriate.

variables are all positively and at least moderately correlated with the measures of venture capital investment, as we would expect.

It is also clear that there may be some co-linearity between the independent variables, particularly between *Deg*, *Fs* and *Pat*. As discussed previously concentrations of financial activity may demand highly qualified staff, likewise patenting activity is shown to be associated with qualified labour. The correlations also suggest a strong association between the level of financial activity and patenting. The Florida and Kenney (1988) model would suggest the presence of hybrid centres in the UK, where high patenting or technology activity and financial activity are co-located. However, we must be careful to interpret *Pat* as a measure of all patenting including large and small firms. Therefore large UK cities may be home to financial services as well as large multinational firms that patent frequently.

We were surprised by the low correlation level of *Ent* with *Fs* and *Pat*, as we might have expected some correlation between the level of business creation and the concentration of financial and technological activity. In fact we find that the concentration of human capital, *Deg*, is weakly negatively correlated with *Ent*. We find the negative correlation is a feature of all regions; in general regional human capital has increased but the level of business creation has slightly decreased from a peak in the late 1980s.

Table 5.4 Correlation co-efficient table

Variable		1	2	3	4	5	6
VC (amount)	1	1					
VC (count)	2	0.979096	1				
Ent	3	0.513422	0.511279	1			
Fs	4	0.661223	0.674756	0.166166	1		
Deg	5	0.550679	0.557873	-0.03569	0.865566	1	
Pat	6	0.662542	0.684259	0.226098	0.861038	0.743339	1

5.4.4 Results of the empirical estimations

In this section we discuss the results of our estimations of equation (4). Our estimations include two alternative dependent variables: VC (amount), and VC (count). Table 5.5 shows the results using VC (amount). Table 5.6 shows the results based on VC (count). In tables 5.7 and 5.8 we explore the regional heterogeneity in the estimation.

The summary estimation statistics in table 6 indicate that model II, with regional cross section fixed effects, is most appropriate. For example this model has the highest adjusted R^2 , the lowest standard error of regression and lowest model selection criterion (Akaike,

Schwarz). Although the addition of period dummy variables in model III returns a fractionally lower sum of squared residuals (SSR) compared to model II, the value of the F-statistic, the proportion of variance explained (adjusted R2), and model selection criteria are inferior to model II. Alternatively, if only period effects are included (model IV) the model has very poor summary statistics with β coefficients that are very different from model II and III.

Table 5.5 also shows that the value of the β coefficients drop considerably from estimation I to II, when the fixed effects are included. This suggests that the dummy cross section coefficients explain a significant amount of variance in investment activity across regions. By including regional dummy variables, the statistical significance of each independent variable is rejected, indicating that only the constants are significant for explaining the amount of regional investment. The signs of the β coefficient in model II also change when we introduced fixed effects. For example *Fs*, *Ent* and *Pat*, become negative, in contrast to *Deg* which remains positive. We also note that the direction of signs on the β coefficient is not as predicted in the reduced form equation (4).

Table 5.5 Estimation summary, dependent variable VC (amount)

VC (amount) Variable	I			II			III			IV		
	β	t-Stat		β	t-Stat		β	t-Stat		β	t-Stat	
C	-0.47	-11.02	*	0.12	6.02	*	0.20	1.54		-0.60	-7.14	*
Ent	51.61	6.71	*	-1.70	-0.82		-1.72	-0.27		-14.42	-1.93	
Fs	0.76	3.12	*	-0.24	-1.14		-0.82	-1.45		2.09	4.10	*
Deg	1.24	3.61	*	0.33	1.78		0.23	0.29		5.37	5.32	*
Pat	1.67	3.09	*	-0.20	-0.46		0.01	0.02		-0.22	-0.24	
Adj R-sq	0.62			0.94			0.93			0.78		
S.E. of reg	0.11			0.04			0.05			0.08		
SSR	1.74			0.28			0.27			0.88		
Log likelih'd	134.60			281.07			283.09			189.62		
Durbin-Wat.	0.29			1.16			1.19			0.47		
Akaike	-1.62			-3.36			-3.15			-2.07		
Schwarz	-1.52			-3.13			-2.56			-1.61		
F-statistic	65.93			213.31			70.02			25.86		
Prob(F-stat)	0.00			0.00			0.00			0.00		
JB statistic	244.65		*	64.49		*	51.71		*	38.98		*

* Statistically significant at 5% level with White cross section error adjustment

The Table 5.6 shows the same estimation sequence using dependent variable VC (count). The estimation shows the same trend of a large drop in coefficient resulting from the addition of regional dummy variables (from model I to II). However, in this case only *Fs*

becomes negative when regional fixed effects are used. The negative sign on F_s was predicted from Table 5.1. Both F_s and Deg are both statistically significant in model II.

Table 5.6 shows that adding period dummy variables in model III appears to make no improvement in explaining venture capital investments. Model II is shown to be the most appropriate according the model selection criterion and the F-statistic. In model IV, adding period effects results strong statistical significance of the individual coefficients but with lower overall explanatory power, as shown by the summary statistics.

More generally we also find that comparing Tables 5.5 and 5.6 shows that the model performs better at explaining the number of deals, than the value of deals. For example, if we compare the estimation results for model II between Table 5.5 and 5.6, we find that the estimations using VC (count) have better model selection criteria, better agreement of the coefficient signs with our predictions in Table 5.1 and more statistically significant coefficients.

Table 5.6 Estimation summary, dependent variable VC (count)

VC (count) Variable	I			II			III			IV		
	B	t-Stat		B	t-Stat		β	t-Stat		β	t-Stat	
C	-0.35	-12.86	*	0.11	7.30	*	0.11	0.93		-0.44	-6.89	*
Ent	40.71	6.73	*	0.60	0.37		0.56	0.11		-18.79	-4.99	*
F_s	0.63	3.65	*	-0.34	-2.99	*	-0.70	-1.82		1.86	6.19	*
Deg	0.89	4.61	*	0.32	2.20	*	0.69	1.13		4.34	6.46	*
Pat	1.62	7.86	*	0.33	1.03		0.53	1.07		0.04	0.06	
Adj R-sq	0.64			0.96			0.95			0.82		
S.E. of reg	0.08			0.03			0.03			0.06		
SSR	1.10			0.12			0.12			0.48		
Log likelih'd	171.48			346.81			349.51			237.24		
Durbin-Wat.	0.18			0.57			0.58			0.35		
Akaike	-2.08			-4.19			-3.98			-2.67		
Schwarz	-1.98			-3.95			-3.39			-2.20		
F-statistic	71.03			327.67			108.47			32.20		
Prob(F-stat)	0.00			0.00			0.00			0.00		
JB statistic	226.38		*	96.87		*	91.38		*	53.09		*

* Statistically significant at 5% level with White cross section error adjustment

As expected the results in table six and seven show evidence for serial correlation with a Durbin Watson statistic <1.5 . This is also a likely explanation for the statistically significant results of the Jacque-Bera (JB) test, which indicates potentially non-normal errors. This supports the use of cross section error adjustment which is applied to the estimations.

The remaining tables in this section are focused on understanding regional heterogeneity. Firstly in Table 5.7 we examine the values of the regional and period effects coefficients resulting from our previous estimations. Then we examine the results from estimating each region as an independent time series, or an unrestricted regression. Finally we test to see whether the unrestricted regression performs better than the fixed effects panel model.

Table 5.7 shows the estimated values of the regional and period effects variables for models II – III. The values shown for each coefficient are reported as deviations from the value of the overall mean constant term, C, as reported in table 5.5 and 5.6. For model II it was also possible to obtain relevant t-statistics for each coefficient, with white cross section error adjustment.

Table 5.7 Regional and period dummy coefficients

	VC (amount)		VC (count)	
	II	III	II	III
C	0.12 *	0.20	0.11 *	0.11
Region effect				
Yorkshire	-0.07 *	-0.07	-0.05 *	-0.05
East Midlands	-0.05 *	-0.06	-0.06 *	-0.06
South West	-0.06 *	-0.05	-0.05 *	-0.04
West Midlands	-0.03 *	-0.03	-0.03 *	-0.03
Wales	-0.10	-0.11	-0.07 *	-0.07
N. Ireland	-0.12	-0.14	-0.10	-0.11
South	0.45 *	0.49	0.35 *	0.35
North	-0.02 *	-0.02	0.01 *	0.01
Period effect				
Minimum		-0.03		-0.02
Maximum		0.03		0.01

* Statistically significant at 5% level

Table 5.7 confirms that adding additional period dummy variables to model II, resulting in model III, provides little explanatory power. The values of the period unobserved effects show only a small deviation from the mean, and this has little implication for the coefficients on the cross section dummies. Therefore we concentrate on model II only.

We also note that the majority of regional dummy coefficients are statistically significant. This shows that venture capital distribution is significantly influenced by unobserved regional factors. The variation in coefficient sizes shows heterogeneity among regions in the size of the regional effect. For example, in model II the dummy variable for the South is much greater than for the other regions. This result indicates that unobserved regional effects in the South, give this region significant advantage in terms of the availability of venture capital investment. For regions like Northern Ireland (and Wales with VC (count)

as dependent variable), the actual coefficient value is not significantly different from zero, suggesting the absence of regional unobserved effects in this region.

Table 5.8 below summarises the range of β_i values obtained for estimates using the two different dependent variables. The table shows a high level of heterogeneity in the coefficient values, with a high level of variance between the minimum and maximum values. The average values, calculated as the arithmetic average as suggested in Pesaran and Smith (1995), also differ from the restricted panel estimates in Tables 5.5 and 5.6. However, in support of our previous panel regressions, we find that the average coefficient values in Table 5.8 tend to show a sign consistent with model II.

Table 5.8 Summary of unrestricted co-efficient estimates (β_i)

		VC(amount)		VC(count)	
Variable		β	t-stat	B	t-stat
C*	min	-0.35		-0.20	
	max	0.69		0.59	
	ave	0.11	6.67	0.10	8.97
ENT	min	-5.55	-0.63	-5.29	-0.35
	max	21.09	4.73	17.11	1.47
	ave	1.78		2.24	
FS	min	-2.84	-4.92	-2.01	-4.28
	max	1.40	3.15	0.36	1.12
	ave	-0.23		-0.15	
DEG	min	-0.71	-1.46	-0.04	-0.09
	max	1.27	2.52	0.96	1.28
	ave	0.40		0.28	
PAT	min	-4.64	-5.71	-2.16	-1.33
	max	2.71	3.64	-0.77	-1.97
	ave	-0.19		-0.38	

* Based on cross section dummy variable, therefore average is reported overall intercept

The full estimation results for each of the β_i coefficients, shown in the appendix, display varied results in terms of statistical significance. For example, estimations using data on the Southern region (labelled as 108) showed a statistically significant relationship between venture capital activity and *Fs* and *Pat*. However, for data series based on Wales (105), all independent variables were insignificant predictors of venture capital activity. Overall the estimation of the β_i coefficients indicated that *Ent* was a poor predictor of regional venture capital activity. However, although *Pat* was insignificant in Tables 5.5 and 5.6, we find that it is actually significant in influencing venture capital activity in three different regions including the South.

The results of the β_i estimations suggest regional heterogeneity with regards to the influence of the independent variables on regional investment activity. However, it is difficult to rely on the statistical significance of the individual β_i coefficients, because of the relatively small sample size of each regions time series. Therefore, we can use a likelihood ratio (LR) and F-test to test for the overall significance of the unrestricted model (β_i) against the fixed effect model (II). The LR test indicates whether restricting the coefficients of each variable to a single value is an acceptable approximation.

In Table 5.9 we show the results of the LR test comparing the unrestricted (β_i) model with the fixed effects model (II), where the regional coefficients are jointly restricted to a single coefficient value. The test strongly rejects the joint restriction of coefficients. Our model of venture capital activity performs better, when each region is allowed an individual coefficient to determine the size of the influence of the independent variables on the level of regional investment activity. This result supports our assessment of the heterogeneity of the relationship of venture capital with supply and demand factors across different regions.

Table 5.9 Unrestricted coefficient test

Test	VC(amount)	VC(count)
Likelihood ratio $\chi_{(28)}$	83.74***	68.36***
F-test $_{(28,120)}$	2.947***	2.284**

Statistically significant at 1%, *Statistically significant at 0.1%

Finally we can test the explanatory power of including regional time varying factors in the model. We can use an LR test to compare the explanatory power of a model which only controls for unobserved effects, against the unrestricted (β_i) model. The results of this test are shown in Table 5.10. It shows that adding regional variables to a specification with only regional constants, does improve its explanatory power.

Table 5.10 Testing the unrestricted model against a constant only fixed effect model

Unrestricted: β_i unrestricted coefficient Restricted: Constant only fixed effect	VC(amount)	VC(count)
Likelihood ratio $\chi_{(32)}$	86.85***	74.19***
F-test $_{(32,119)}$	2.703***	2.212**

However, we note that a constant only fixed effect specification¹¹ accounts for a high proportion of the variance in investment activity. For example in terms of the VC(amount) and VC(count) series, the constant only specification explains 94% and 96% respectively, of the variance. Therefore, adding the independent variables with unrestricted coefficients

¹¹ A constant only restriction was tested against model (II), the constant only specification restriction was accepted against model (II).

to a constant only model results in an increase of the adjusted R^2 statistic by 1.7% and 0.9%, for the VC(amount) and VC(count) models respectively.

5.5 Conclusion

This chapter confirms the widely held view that the regional distribution of venture capital is uneven across UK regions. However, our analysis also sheds light on the factors associated with this uneven distribution. On the supply side there is evidence that the concentration of financial services influences the supply of venture capital. Financial services activity was shown to negatively influence investment in the reduced form equation for the fixed effect model (II). This is consistent with our expectations outlined in Table 5.1.

On the demand side we find the influence of entrepreneurship on the level of regional venture capital to be statistically weak, with little evidence to suggest that the level of business creation is important to venture capital investment. One explanation for this result, in line with our discussions in Chapter 2, is that UK venture capitalists prefer investing in more established business, rather than start-up firms.

Our analysis in this chapter also indicates that another regional demand side factor, the concentration of professionally qualified employees, has a statistically significant influence in determining the number of regional venture capital deals. The direction of influence of this factor is shown to be consistently positive in the fixed effects models, and positive on average in the β_i models. The positive value also fits with our prediction of the coefficient values in Table 5.1. In light of Table 5.1 the result for the influence of professional employees also agrees with the direction of influence reported for financial services and entrepreneurship.

In contrast, there is little evidence for a consistent influence of the regional technological activity on venture capital. The concentration of technological activity is insignificant in the fixed effect model and the direction of influence varies across individual regions. We find that the average values from the unrestricted β_i models are negative. The influence of technology activity is inconsistent and does not agree with our predictions in Table 5.1 or with the pattern of our results for the other variables.

There are two possible explanations for the inconsistency of the explanatory power of technology activity. Firstly that in agreement with our discussion of entrepreneurship that

our measure of venture capital activity based on BVCA membership activities does not represent investment in innovative new technology companies. Or secondly that our measure of technology activity, based on patenting, captures large firm innovation or development activity, as well as small firm innovation activity. The implication is that large firm activity is less influential in creating demand for venture capital and complicates our interpretation of the estimations.

Our results clearly show that unobserved regional effects account for a large proportion of the variance explained in the models, whether we look at the volume of deals or value of investment in a region. The distribution of venture capital is largely explained by a constant for each region, suggesting a low variation in the regional distribution of venture capital over the twenty year period. This indicates the presence of long term processes that have fixed the level of venture capital investment a region receives. This analysis would appear to agree with Martin et al (2005) observation of the persistence of winner and loser regions. It implies that regional venture capital activity is concentrated to specific locations which have a long history of embedded regional activity.

The regional dummies in the fixed effects estimations show that the southern region of the UK has a strong advantage over other locations with respect to investment activity. The large size of the regional dummy for the South with respect to other regions, suggests venture capital is embedded in the region. In agreement with our discussion of the literature in Chapter 2 supports the view that London acts as centre for venture capital activity. It follows that the Southern areas generally benefit from proximity to the wider financial community in the capital. Thus in future, London and the Southern regions are likely to maintain their dominant share of total venture capital activity.

An important finding in this chapter, consistent with the view that UK venture capital activity is concerned with late stage investments in established businesses, is the absence of a strong association of venture capital distribution with regional high technology clusters or entrepreneurial activity. In the next chapter we see whether we can improve the performance of our model by focusing only on early stage investment activity.

The use of fixed effect estimation has demonstrated the regionally embedded nature of venture capital, but is inadequate for investigating this further, as time constant variables are removed in the fixed effects transformation. Our estimation routine would benefit from the use of more advanced techniques to include a lagged specification to account for the

serial correlation shown, or to account for spatial correlation. However, the presence of strong heterogeneity in our results creates problems for the implementation of panel techniques.

Finally, we note that our discussions of the results are based on the reduced form coefficients. These reduced form coefficients are effectively ‘scaled’ by the coefficients of the network work variable. Our analysis tells us whether these variables are influential and the size of their influence scaled by the influence of networking. In the absence of appropriate time series measures of the level of region network activity¹², we can only recover the structural coefficients by applying assumptions to restrict the value of the network coefficients. Our assessment of the direction of influence of the independent variables suggests that our results fit the assumption that the coefficient of networking activity is greater on supply than demand. We continue the discussion of the validity of this assumption in the next chapter.

¹² An alternative which is not investigated here would be to use a proxy for the entrepreneurial networking activity variable. One option for future study would be to use the industrial structure of regions, such as firm sizes, to proxy for the level of small firm or entrepreneurial network activity.

Geography of early stage venture capital

5.6 Introduction

In this chapter we continue exploring our first thesis research question using the model proposed in Chapter 5. However in this chapter we use a more focused database that captures early stage venture capital investment. Our decision to repeat the analysis in this way is motivated by the fact that we know the data used in Chapter 5 contains ‘merchant’ type investment activity which dominates UK investment activity. The larger value of ‘merchant’ type investments has the potential to skew our estimation results.

‘Classic’ type of venture capital is likely to be concentrated on early stage finance.

However, as we note in Chapter 4, data on early stage investment activity is difficult to obtain from secondary sources. In this chapter we utilise a new database on SME firms receiving venture capital, which is used to derive data on regional early stage investment activity. This also provides the opportunity to disaggregate the venture capital data by sector and look for variations in the pattern of the distribution of investment by sector.

In the UK, the prevalence of pockets of concentration of venture capital activity (e.g. in the South) has been cited as one of the main reasons for the creation of regionally based venture capital funds via a Government initiative. The initiative led by the Department for Trade and Industry (DTI) has been designed to provide locally based access to early stage venture capital across UK regions. This also includes the provision of funding for biotechnology.

Among hi-technology sectors, the biotechnology sector is strongly dependent upon venture capital funding (Powell et al, 2002). Biotech businesses frequently have a high financial capital requirement because of the long product development times and high costs of research and development. In particular, the high level of technological risk and long product development times in biotechnology innovation has meant that venture capital and public investment are an important source of finance for entrepreneurial biotechnology firms (Sainsbury, 1999). Thus, public investment in biotechnology constituted 20% of all venture capital deals (4% in value) in biotechnology between 2000-04, compared to just 8% for all other sectors deals (1% in value) that received venture funding in the same period.¹³

¹³ Author’s calculations from Library House database

Against this background of debate about regional concentration of venture capital and the targeting of biotechnology by government venture funds in the UK, the aim of this chapter is two-fold. First, we wish to investigate whether the distribution of early stage venture capital investment in the UK can be explained by regional variables such as local entrepreneurship, availability of financial services, extent of R&D and the availability of human capital. Second, we wish to investigate whether the factors affecting venture capital investment in biotechnology are different from those affecting venture capital investments in other technology sectors.

The remainder of the chapter is organised in the following way. First we add to our review of biotechnology and venture capital in Chapter 2. In particular we focus on the role of venture capital in the development of biotechnology in order to draw out a supply-demand based framework to explain the availability of venture capital. Then we develop this framework into an econometric model, similar to that in Chapter 5, and discuss the methodological issues involved in implementing such a statistical estimation. Next we outline the main characteristics of the data used in the analysis, including descriptive statistics that demonstrate the sector-specific and regional differences in venture capital availability. Finally we report the results of the econometric estimations and discuss the implications of those results before we conclude the chapter.

5.6.1 Venture capital in the supply – demand framework

The theoretical position of this chapter builds on our discussions in Chapter 2 and Chapter 4. We continue with our approach from Chapter 4 to test whether the Florida and Kenney (1988) type model applies to the UK, namely, that those regions with a concentration of financial capital, technological capital and human capital will receive high levels of investment.

Our literature review in Chapter 2 indicated that regions which receive investment in biotechnology have a strong association with technological and human capital. High concentrations of technological and human capital signal regions with investment potential and attract investment. However, it is also clear that biotechnology investment is focused in specialist locations, and therefore the general Florida and Kenney model may not apply to an individual sector such as biotechnology.

Public investment into firms is expected to be targeted at regions with a low supply of private venture capital. UK policy has been directed towards providing funding to correct

for perceived funding gaps, and to provide a more even supply of capital. In general, it is expected that regions with a high proportion of public funding will receive lower amounts of funding in total. For example, if a region received 100% of its investment from a public source, this would indicate the absence of any private investment; an unhealthy investment situation. We would expect a region with such a high level of public investment to have lower overall levels of venture capital activity. Therefore, we expect the regional proportion of total investment from a public source will have a negative association with venture capital investment supply.

The strong relationships between public research institutions and the creation of investment opportunities, particularly in biotechnology, may suggest that regions with increased public R&D will demand more venture capital finance to develop these opportunities. However, privately funded R&D may also generate investment opportunities for venture capitalists, through corporate spin outs, where the parent company wishes to diversify some financial risk. We follow the emphasis in the biotechnology literature on university spin outs; therefore we expect that regions with high levels of publicly funded R&D will demand more VC.

Powell et al, (2002) observed that for US biotechnology firms there was a strong relationship between venture capitalist investors and research and development (R&D) centres. Concentrations of R&D were found to generate the ideas and intellectual materials from which commercial opportunities arose. However, Powell et al (2002) also observed that biotechnology investment was strongly concentrated in a small number of specialised locations; only certain research centres had an associated concentration of biotechnology firms (ibid).

In line with Chapter 5 these factors and theoretical positions are used to create a model of regional venture capital investment in the UK, which is presented next. The remainder of this chapter will present the method used to test the model, and the results which include descriptive and regression based analysis.

5.7 Method

5.7.1 Model

We adopt the model outlined in Chapter 5, making some changes to the variables used because of changes to data. As before, only a static reduced form equation will be estimated. The reduced form equation is derived from the following (1) demand, (2)

supply and (3) equilibrium equations for venture capital activity (VC_{it}), indexed for each region, i and year, t :

$$\begin{aligned} (1) \quad VC(d)_{it} &= \beta_1 + \beta_2 Ent_{it} + \beta_3 Deg_{it} + \beta_4 R \& D_{it} + \beta_5 Net_{it} + \beta_6 R \& Dratio_{it} \\ (2) \quad VC(s)_{it} &= \alpha_1 + \alpha_2 FS_{it} + \alpha_3 Net_{it} + \alpha_4 VC_public_{it} \\ (3) \quad VC(d)_{it} &= VC(s)_{it} \end{aligned}$$

The independent variables familiar from Chapter 3 are entrepreneurship (Ent_{it}), financial capability (FS_{it}), professional capability (Deg_{it}), technological capability ($R\&D_{it}$), networks (Net_{it}). We also add two new variables public investment (VC_public_{it}), public R&D ($R\&Dratio_{it}$) to capture the role of public investment. A full description of how these variables are measured and descriptive statistics are included in the data section.

The independent variables in equation (1) and (2) are expected to have a positive influence on the corresponding dependent variable. Assuming the above are linear equations, they can be equated for the equilibrium equation, and the supply equation can be solved for Net and substituted in the demand equation. This reduced form equation gives the level of venture capital activity:

$$\begin{aligned} (4) \quad VC_{it}(\theta) &= \pi_1 + \pi_2 Ent_{it} + \pi_3 Deg_{it} + \pi_4 R \& D_{it} + \pi_5 FS_{it} + \pi_6 R \& Dratio_{it} + \pi_7 VC_public_{it} \\ \text{Where :} \\ \pi_1 &= \frac{\beta_1 \alpha_3 - \beta_5 \alpha_1}{\alpha_3 - \beta_5} \quad \pi_2 = \frac{\beta_2 \alpha_3}{\alpha_3 - \beta_5} \quad \pi_3 = \frac{\beta_3 \alpha_3}{\alpha_3 - \beta_5} \quad \pi_4 = \frac{\beta_4 \alpha_3}{\alpha_3 - \beta_5} \\ \pi_5 &= \frac{-\beta_5 \alpha_2}{\alpha_3 - \beta_5} \quad \pi_6 = \frac{\beta_6 \alpha_3}{\alpha_3 - \beta_5} \quad \pi_7 = \frac{-\beta_5 \alpha_4}{\alpha_3 - \beta_5} \end{aligned}$$

As in Chapter 5 we summarise our expectations in Table 6.1. We show how our expectations for the influence of each factor in the structural supply and demand equations, translate into the reduced form model, where, as in Chapter 5, the outcome also depends on the scaling by Net .

Table 6.1 Theoretical predictions of the influence of supply and demand variables

Structural form variables	Influence on:	Direction of influence in structural form	Direction of influence in reduced form*	
			If $\alpha_3 > \beta_5$	If $\alpha_3 < \beta_5$
Ent	VC(d)	+ve	+ve	-ve
Deg	VC(d)	+ve	+ve	-ve
R&D	VC(d)	+ve	+ve	-ve
R&D ratio [#]	VC(d)	+ve	+ve	-ve
Fs	VC(s)	+ve	-ve	+ve
VC public	VC(s)	-ve	+ve	-ve
Net	VC(s)	+ve	N/A	N/A

*Assuming Net has positive influence on supply and demand equations, otherwise predictions for reduced form do not hold
[#] Assuming that increasing public investment will increase demand for venture capital and give the expected coefficient signs for the reduced form equation on this basis.

5.7.2 Issues in estimation

We use our early stage investment data to generate three versions of the model, using three different dependent variables. Firstly we estimate the model using all early stage investment (*All deals*), then we partition the early stage data in two, and estimate a model using biopharmaceutical investment (*Biopharma*), and then estimate a model on the remaining sectors of investment activity (*Rest of sectors*). In each version of the model the independent variables remain the same. The only exception is *VC_public* which we adjust to match the type of sectoral activity described by the dependent variable. As in Chapter 5 we estimate each version twice using the count of deals and then the value of investment made in a region.

In this chapter we take natural logarithms of the data used to estimate the model. Therefore, the reduced form equations are estimated using a log-log specification. The coefficients produced from a log-log specification can be interpreted as elasticities. An elasticity coefficient has the advantage of having a dynamic interpretation. The elasticity coefficient value indicates the percentage movement in the dependent variable resulting from a 1% movement of the respective independent variable. For example, a coefficient value for *Ent* in the regression of 5.4, would indicate that a 1% change in the value of *Ent* would result in a 5.4% change in the amount or number of venture capital deals. Therefore a log-log specification is helpful when trying to understand the relative impact of different factors on the dependent variable. By using coefficients of elasticity it also simplifies comparing the results of the different versions of the model. This helps when comparing biotechnology with other sectors, or comparing the influence of our independent variables on the number of regional deals against the value of deals.

A final advantage of the log-log specification is that it reduces the chance of our coefficients being affected by time trends or spurious relationships in the data. In order to take logarithms of the dataset a transform of $\log(x+1)$ is applied to allow for the presence of zero values in some of the series. This transform has little impact on the associations between the transformed series, but prevents the zero value from being excluded.

As with Chapter 5 we use panel regression to estimate the coefficients of each version of the model. We also use the Hausman test to determine that fixed effects are preferred to random effects. We also find the presence of heteroskedasticity and mild levels of first order serial correlation. As we will see in section 6.2.3, our dataset in this chapter is relatively small; therefore we can expect the presence of a certain level of non-normality of

errors. As in Chapter 5 we correct for non-normality in the error test using white cross section robust covariance.

However, the specification and diagnostic tests revealed several differences to those obtained in Chapter 5. For example, we find that fixed effects are insignificant for some versions of the model. Table 6.2 shows the results of the F-test for the redundancy of fixed effects. The table shows that the presence of time constant regional effects is statistically weaker for the regression of the *Biopharma* sector. This suggests that specific regional factors are less important for investments in the biopharmaceutical sector. In particular the *Biopharma* count and value model reject the use of fixed effects over panel least squares at the 5% level, suggesting that only a restricted single intercept model should be estimated. However, for the *Rest of sectors*, and *All deals* models fixed effects are significant. To allow for this variation we report the results of the least squares regressions in the chapter’s appendix and show the fixed effects estimation in the results section.

Table 6.2 F-test of the joint significance of fixed effects vs. least squares

Model	Sector		
	Bio/pharma	Rest of sectors	All deals
Count model	N/S	***	***
Value model	*	***	***

N/S Not significant, ***1% confidence level, ** 5% confidence level, * 10% confidence level.

A second difference from our estimations in Chapter 5 is that some of models in this chapter are diagnosed with the presence of endogeneity regarding entrepreneurship. The results of the Hausman test showed the presence of endogeneity in the regressions for the biopharma model at the 5% significance level. To control for the potential bias produced from endogeneity we apply an instrumental variable and use the two stage least squares regression technique. The level of regional unemployment (*Claim*) was found to be an appropriate instrumental variable for entrepreneurship using Stock and Watson’s (2003) procedure¹⁴. We discuss the result of the two stage least squares regressions for the biopharmaceutical models in the results section of this chapter.

5.7.3 Data and variables

Although individual series may have long time series, to obtain a balanced panel the dataset used in this chapter is for the period 2000-2003. However, in contrast to Chapter 5 we have data for the 12 UK Government Office Regions (GOR) regions, giving each series 48 data points. The UK GOR disaggregate the data along political/administrative

¹⁴ Based on an F-test of the significance of the first stage regressors.

boundaries where Wales, Scotland and Northern Ireland are included at the national level whereas England is broken down into a further nine regions. The GOR are considered the “primary classification for the presentation of regional statistics” in the UK (National Office of Statistics).

5.7.3.1 Variables

The dependent variables for venture capital activity are given as the number of deals and value of investments. These are calculated from the Library House dataset as outlined in Chapter 2. The independent variables *Ent*, *Fs*, *Deg*, *R&D*, *R&D ratio* are included as ratios, as shown in Table 6.3, to standardise for the different geographical sizes of regions. Standardising variables in this way helps to reduce the potential for spurious regression arising from factors such as background population growth over the period. The variable *Claim* is used as an instrumental variable for *Ent*.

As we discussed the collection of data for the independent variables in Chapter 5, here we limit our discussion to the additional variables included in the model, *VC_public*, *R&D* and *R&D ratio*. The variable *VC_public* is calculated as the proportion of deals (by count or value) that include finance from a public source. In a minority of deals, public investors syndicate with private investors, inflating the size of the public contribution. However, as we shall see in Chapter 7 this is the exception, rather than the rule. We generate an approximate measure of the level of funds from public institutions in the dataset. One complication is that private firms are sometimes used to run or manage public funds, for example the RVCF. As these investors also manage other private funds we cannot include these as public finance. In RVCFs the public funds contribute to approximately 30%¹⁵ of the total fund involvement. As the RVCF may syndicate with other investors this further reduces the relative size of the public contribution.

In this chapter we use R&D data from EUROSTAT instead of patent applications to measure the regional concentration of technological activity. Although EUROSTAT’s patent data has a long time series, it is missing values for Scotland. The R&D data¹⁶ is populated for each region in our analysis, and also disaggregates according to public and private investment in R&D. This provides the opportunity to include a measure of the ratio

¹⁵ According to interview with RVCF fund manager.

¹⁶ Our measure of R&D is a general measure of UK research and development, where R&D definition is that used by the Organisation for Economic Cooperation and Development (OECD) defined as, “Creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications”. One implication of our R&D measure is that this includes research relating to new innovation as well as the development of existing innovation.

of public to private R&D investment in each region. One implication of using R&D investment is that this might capture investments to improve existing innovation and therefore be biased towards development of existing products, rather than the creation of new innovations. We summarise the data series and respective data sources in Table 6.3 below.

Table 6.3 Description of data and sources used in chapter

Series	Description	Source
VC count	Count of VC deals	Library House database
VC value	Value of VC investment	Library House database
Ent	Number of new VAT registrations per civilian labour population	NOMIS, Office of National Statistics
Fs	Number of financial services employees per employee population	Regional Trends publication, Office of National Statistics
Deg	Number of degree qualified people per working age population	Regional Trends publication, Office of National Statistics
VC_public	Proportion of public investment (deals or value)	Library House database
R&D	Investment into R&D per civilian labour force	EUROSTAT online
R&D ratio	Ratio of public/private R&D investment	EUROSTAT online
Claim	Number of long term unemployed claiming benefit	Regional Trends publication, Office of National Statistics

5.8 Results

5.8.1 The distribution of venture capital investment

The distribution of venture capital in the UK is known to be uneven and Table 6.4 reflects this observation. The table shows the total count and value of deals made between January 2000-September 2006 in the UK, split by GOR, for *Biopharma* investments and the remaining sectors and then the totals for all deals.

During the period a total of £10bn is recorded as being invested in the UK in over 4000 deals. The table clearly shows that there is a wide variation in the level of venture capital activity in regions across the UK for both types of technology investment. The highest *Biopharma* funded region was the East (£600m), which received over a 500 times more funding than the West Midlands (£1m). Over the same six year period London received the highest level of funding for the other sectors (£3bn) which was around 50 times larger than the lowest funded region, suggesting less variation between the highest and lowest funded regions for this sector grouping. It is also clear from this table that regions such as the East, North East and Yorkshire have a high proportion of investment into biotechnology compared to the rest of the sectors.

Table 6.4 Investment by deal and value – Library House dataset

Region	Bio/pharma		Other sectors		All	
	Deals	Value £000's	Deals	Value £000's	Deals	Value £000's
East	177	602,410	464	1,040,417	641	1,642,827
E.Midlands	19	11,268	107	92,953	126	104,221
London	79	211,913	877	3,111,905	956	3,323,818
N.Ireland	4	1,775	67	92,037	71	93,812
N.East	26	25,723	92	51,986	118	77,709
N.West	33	105,949	232	382,274	265	488,223
Scotland	62	225,733	361	591,866	423	817,599
S.East	107	462,410	668	1,827,047	775	2,289,457
S.West	37	70,865	154	553,891	191	624,756
Wales	13	3,614	100	98,718	113	102,332
W.Midlands	5	1,093	233	512,688	238	513,781
Yorkshire	33	24,982	119	211,436	152	236,418
Total	595	1,747,735	3474	8,567,218	4069	10,314,953

Source: Author’s computations on Library House data

Presenting the deal information from table one, in terms of regional shares of the total investment activity in the UK, reflects the distribution of venture capital investment. It also allows a statistical comparison to be made between the different patterns of distribution between *Biopharma* and the *Rest of sectors* investment.

Table 6.5 also shows that four regions, the East, London, South East and Scotland, account for around 70% of all venture capital activity regardless of technology type, although the order of importance of the UK regions does vary with the type of technology.

Table 6.5 Regional shares of UK investment total

Region	Bio/pharma		Rest		z-test significance	
	Countshare	Valueshare	Countshare	Valueshare	Countshare	Valueshare
East	30%	34%	13%	12%	***	***
E.Midlands	3%	1%	3%	1%		
London	13%	12%	25%	36%	***	***
N.Ireland	1%	0%	2%	1%		
N.East	4%	1%	3%	1%		
N.West	6%	6%	7%	4%		
Scotland	10%	13%	10%	7%		**
S.East	18%	26%	19%	21%		
S.West	6%	4%	4%	6%		**
Wales	2%	0%	3%	1%		
W.Midlands	1%	0%	7%	6%	***	***
Yorkshire	6%	1%	3%	2%	*	
	100%	100%	100%	100%	-	-

*This statistic was calculated comparing the overall shares of investment activity (countshare) in both technology types for each. *** 1% confidence level, ** 5% confidence level, * 1% confidence level. Percentages are based on the totals in Table 3, and sample size = 762 deals.

The comparison of proportions z-test shows a statistically significant difference between biotechnology investment shares and the remainder of investments for certain UK regions when evaluated at a 90% confidence level. This result suggests that *Biopharma* investment follows a different regional trend to the *Rest of the sectors*.

The East and Yorkshire show a significant positive statistic indicating a relatively higher share of UK biotechnology deals compared to the regions share of other sectors investment. We would expect the East, centred on Cambridge, to feature strongly in biopharmaceutical activity. The data also pick out that Yorkshire is relatively specialised in biopharmaceutical activity compared to the other sectors receiving investment. One additional observation is that Scotland takes a consistent proportion of the number of deals whether we look at biopharmaceuticals or the other sectors. However, we find that in terms of the value of deals, Scotland's biopharmaceutical investments outperform, taking a larger slice of the total investment made. We will return to this point later on in the chapter.

Interestingly, London and the West Midlands show a lower share of biotechnology deals compared to their activity in the other sectors, suggesting that biotechnology is less prominent in these regions compared to other types of opportunities. Therefore, although London is the second largest region in terms of biopharmaceutical investment, we find that compared to the East, biopharmaceutical investment in London is a much smaller part of the regions overall activity. To make greater sense of these results, in Chapter 10 we reflect on the biopharmaceutical organisation of regions such as the East, London, Scotland and Yorkshire in more detail, to understand the activities underlying these regional investment totals.

These results provide evidence for relative regional strengths and weaknesses of regional venture capital funding overall. We also show that biotechnology investment does not necessarily follow the general pattern of regional investment. In Table 6.6 we show the proportion of investment activity within each region that can be traced to a public source. As with Table 6.5 our purpose is to compare these regional proportions across the two technology categories.

Our first observation is that overall the proportion of finance in biopharmaceuticals from a public source is 20% by deal count and 5% by value. On average, in non-biopharmaceutical sectors the proportion of public finance is lower, 10% by deal count and only 1% by deal value. As we discussed in the literature review, this is likely to be a result of the Governments perception of biotechnology as a priority area for support.

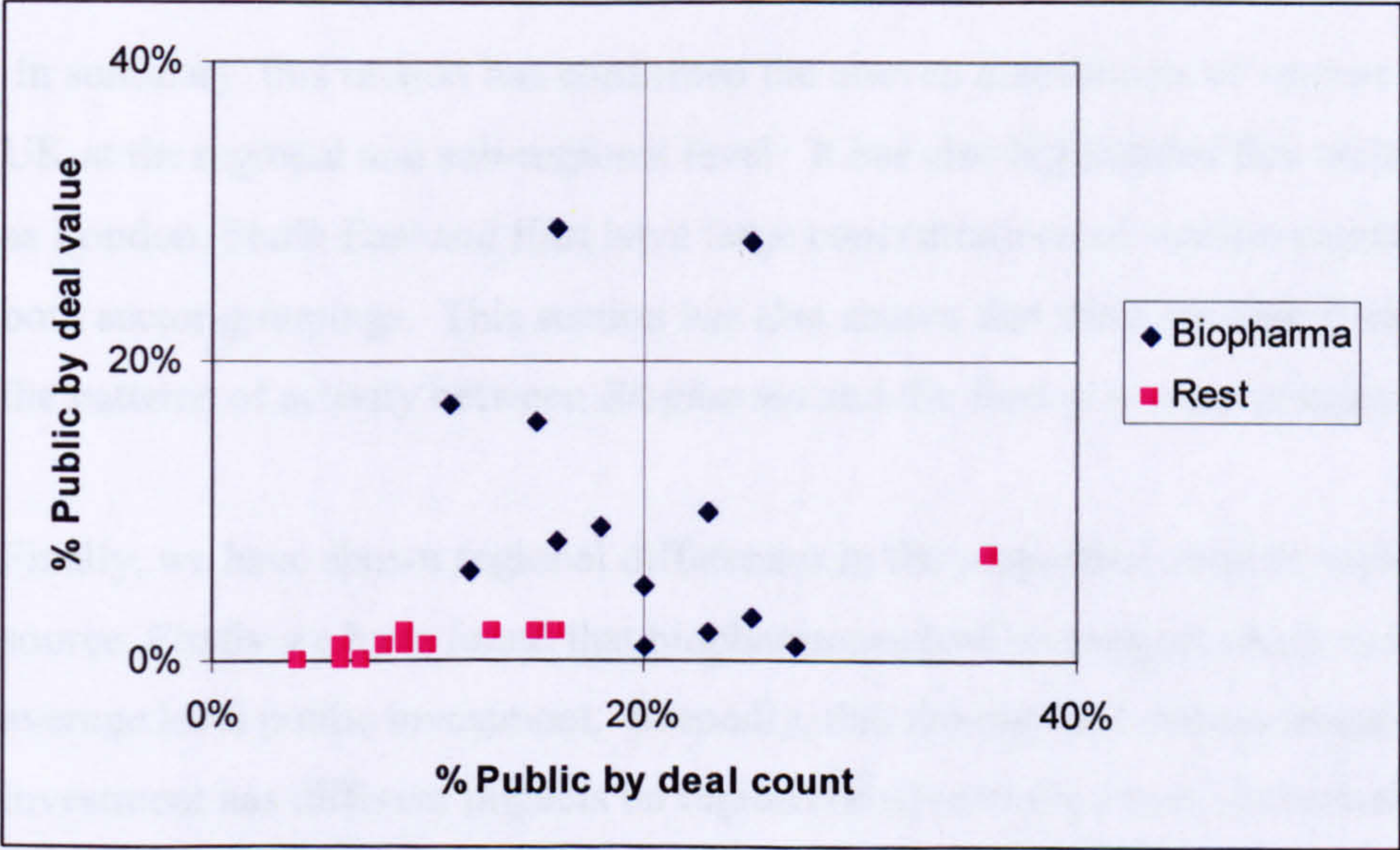
Table 6.6 Public investment as a proportion of total investment in each sector

Region	Bio/pharma		Rest		z-test	
	Count	Value	Count	Value	Count	Value
East	23%	2%	13%	2%	**	
E.Midlands	16%	29%	13%	2%		**
London	25%	3%	6%	0%	***	**
N.Ireland	25%	28%	36%	7%		
N.East	23%	10%	15%	2%		
N.West	18%	9%	7%	0%		*
Scotland	27%	1%	16%	2%	*	
S.East	16%	8%	8%	1%	*	**
S.West	11%	17%	9%	2%		***
Wales	15%	16%	9%	1%	*	*
W.Midlands	20%	1%	6%	1%		
Yorkshire	12%	6%	4%	0%		
GrandTotal	20%	5%	10%	1%	***	***

The z-test sample is different for each region, as it's based on the number of deals in each region rather than the total UK population in Table 4. This may affect the significance for results for regions with a low number of deals e.g. Northern Ireland. Public investment expressed as a proportion of total investment made into each technology sector, i.e. public investment into *Biopharma*/total investment into *Biopharma*.

Thus, we find a mixed picture of public support. We can illustrate these complexities using the scatter plot in Figure 6.1 below. Figure 6.1 is divided into four quadrants. The lower left quadrant contains the majority of regions, particularly according to their public investment into sectors other than biopharmaceuticals. For Regions in the lower left quadrant, such as the North West and South East, direct public investment is not a strong a feature of the total regional investment activity; it contributes to less than 20% of the total investment by count or value.

Figure 6.1 Scatter plot of public investment, deal count against deal value



Regions in the lower right quadrant, (mainly in terms of *Biopharma* activity), have a relatively high proportion of deals involving public sources. However, this quadrant is

characterised regions where public deals have a low financial impact relative to the total investment made in the region. In these regions public finance acts in a ‘pump priming’ role, seeding opportunities. This quadrant includes biopharmaceutical activity in the East, London and Scotland. Only one region, Northern Ireland is included for activity relating to non biopharmaceutical investment.

The top quadrants include only two regions where the value of public investment in biopharmaceutical deals contribute to greater than 20% of the overall activity in the region. We have already noted that Northern Ireland is very dependent on public investment, and this region is located in the top right quadrant. The top left quadrant contains the East Midlands where the public deals have received a relatively high proportion of public finance. Although we note that Table 6.4 indicates a low level of total investment in the East Midlands region, which explains the predominance of public investment.

Table 6.4 also indicates that differences between the proportion of public funded deals, in biopharmaceuticals and the rest of sectors are statistically significant. For example the main investment regions identified in Table 6.3 (London, East, South East) have a much higher proportion of public deals in *Biopharma* compared to the *Rest of sectors*. In terms of the relative value of public investment to total regional investment, places such as the East Midlands and the South West, which have low levels of funding in general, show a much higher proportion of public investment in *Biopharma* compared to the *Rest of sectors*.

In summary, this section has confirmed the uneven distribution of venture capital in the UK at the regional and sub-regional level. It has also highlighted that certain regions such as London, South East and East have large concentrations of venture capital activity in both sector groupings. This section has also shown that there are significant differences in the patterns of activity between *Biopharma* and the *Rest of sectors* grouping.

Finally, we have shown regional differences in the proportion venture capital from a public source. Firstly we have found that biopharmaceutical investment receives a higher than average level public investment. Secondly, that the regional disbursement of public investment has different impacts on regions relative to their total investment activity. The impacts of public investment vary from a pump priming role - increasing deal making to a significant contribution to regional investment.

5.8.2 Descriptive statistics

The descriptive statistics for the logarithms of variables in the panel data set for the 12 GOR regions 2000-2003 are given in Table 6.7 below. The statistics are given for the dependent variables, *Biopharma* and the *Rest of sectors* with their combined total named *All deals*, in terms of the count of deals (VC_count) and value of investment (VC_value). The next section of the table gives the descriptive statistics for the independent variables, including the proportion of public investment in each sector group by count and value. Finally the statistics for the instrumental variable *Claim* are given.

Table 6.7 Descriptive statistics of the panel dataset

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
VC_count:							
<i>Biopharma</i>	1.56	1.50	3.53	0.00	1.03	0.05	2.26
<i>Rest of sectors</i>	3.29	3.14	5.20	1.79	0.89	0.42	2.01
<i>All deals</i>	3.44	3.26	5.23	1.79	0.90	0.40	1.94
VC_value:							
<i>Biopharma</i>	6.81	7.25	12.29	0.00	4.05	-0.65	2.15
<i>Rest of sectors</i>	10.57	10.62	13.73	5.99	1.71	-0.40	2.74
<i>All deals</i>	10.74	10.82	13.77	5.99	1.74	-0.42	2.70
Independent:							
<i>Ent</i>	0.09	0.10	0.12	0.06	0.01	-0.65	4.03
<i>FS</i>	0.21	0.20	0.34	0.10	0.06	0.58	3.38
<i>Deg</i>	0.14	0.12	0.22	0.09	0.03	1.46	4.81
<i>R&D</i>	0.44	0.44	0.94	0.22	0.19	0.97	3.13
<i>R&D ratio</i>	0.53	0.46	1.01	0.19	0.28	0.33	1.52
VC_public:							
<i>Biopharma deals</i>	0.15	0.18	0.51	0.00	0.15	0.45	2.08
<i>All deals</i>	0.12	0.10	0.45	0.00	0.08	1.37	6.16
<i>Rest of sectors deals</i>	0.10	0.09	0.45	0.00	0.09	1.48	6.12
<i>Biopharma value</i>	0.12	0.01	0.69	0.00	0.21	1.79	4.68
<i>Rest of sectors value</i>	0.02	0.00	0.19	0.00	0.04	3.08	12.49
<i>All deal value</i>	0.03	0.01	0.21	0.00	0.04	2.74	10.76
Instruments:							
<i>Claim</i>	4.40	4.33	5.24	3.56	0.41	0.11	2.28

*Skew expressed as difference from normal distribution, the kurtosis of the normal distribution equals three.

The first observation is that there are regions without biopharmaceutical venture capital activity in certain years as shown by the zero minimum value for all of VC_count and VC_value series, although all regions did have investment in biopharmaceuticals at least once in the period 2000-2003. The range (maximum-minimum) for the VC_count series show similar values across the sector groupings. However, the range for the VC_value series is much larger due to certain regions receiving very high amounts of investment. As anticipated from the tables presented earlier, the mean values for the *Biopharma* series are much lower than the statistics for the rest of sectors series.

The log transform of the variables also has the benefit of increasing the normality of the data series distribution. Only the *VC_public* series based on the value of investment in the

Rest of sectors and *All deal* series show strong evidence of a non-normal distribution. These series have excess kurtosis and skew, when compared to the normal distribution, because of a high occurrence of zero values.

Next we use Pearson correlations to evaluate any basic pairwise associations between variables in the dataset. The correlation analysis provides a preliminary indication of any relationships between the transformed dependent and independent variables. The correlations reported in Tables 6.8 and 6.9 are based on the panel data for the period 2000-2003. Table 6.8 uses the count of deal and Table 6.9 reports that correlations based on the value of deals.

Table 6.8 Log model: VC count series

Variables	1	2	3	4	5	6	7	8	9	10
VC_count:										
1 Biopharma	1.00									
2 Rest of sectors	0.68 ***	1.00								
3 Bio VC_public	0.42 ***	0.16	1.00							
4 Rest VC_public	-0.15	-0.18	-0.07	1.00						
5 Ent	0.21	0.58 ***	-0.05	-0.15	1.00					
6 Fs	0.46 ***	0.79 ***	0.05	-0.12	0.85 ***	1.00				
7 Deg	0.45 ***	0.73 ***	0.17	-0.11	0.51 ***	0.80 ***	1.00			
8 R&D	0.62 ***	0.59 ***	0.08	0.12	0.34 **	0.58 ***	0.46 ***	1.00		
9 RDratio	0.09	0.09	0.20	-0.27	-0.02	-0.06	0.15	-0.57 ***	1.00	
10 Claim	0.03	0.38 **	0.01	0.03	0.75 ***	0.62 ***	0.41 ***	0.02	0.28 *	1.00

Table 6.9 Log model: VC value series

Variables	1	2	3	4	5	6	7	8	9	10
VC_value:										
1 Biopharma	1.00									
2 Rest of sectors	0.49 ***	1.00								
3 Bio VC_public	0.10	-0.06	1.00							
4 Rest VC_public	-0.09	-0.27 *	0.00	1.00						
5 Ent	0.22 *	0.65 ***	-0.16	-0.08	1.00					
6 Fs	0.42 ***	0.75 ***	-0.18	-0.04	0.85 ***	1.00				
7 Deg	0.39 **	0.61 ***	-0.10	-0.06	0.51 ***	0.80 ***	1.00			
8 R&D	0.46 ***	0.48 ***	-0.14	0.09	0.34 **	0.58 ***	0.46 ***	1.00		
9 RDratio	0.15	0.07	-0.01	-0.27	-0.02	-0.06	0.15	-0.57 ***	1.00	
10 Claim	0.10	0.47 ***	-0.17	-0.07	0.75 ***	0.62 ***	0.41 ***	0.02	0.28 *	1.00

All correlations for data between 2000-2003 for 12 UK Government regions (N=48) ***1% confidence level, ** 5% confidence level, * 10% confidence level

Table 6.8 shows a moderate relationship (0.68) between *Biopharma* and *Rest of sectors* in terms of the number of deals. This association suggests regions with high levels of deals in biopharmaceuticals are also likely to have high levels of investment into other sectors. The same relationship is weaker (0.49) when the amount of investment is considered in Table 6.9. This result is generally consistent with the discussion of Table 6.3.

Interestingly the correlations for both venture capital deal series (*Biopharma* and *Rest of sectors*) show a significant association for *Fs*, *Deg* and *R&D* by count and value of deals. The smaller correlation coefficients of these variables with *Biopharma* compared to the *Rest of sectors* indicate that the importance of these factors to biopharmaceutical investment may be different.

The *R&D* series is strongly correlated with both *Biopharma* and *Rest of sectors*. In general the strength of the correlation between *R&D* and the two VC series are similar. The strength of the association of *R&D* is slightly lower for correlations based on the value of investment (*VC_value*) compared to the number of deals (*VC_count*). However *R&D ratio* is very weakly positively associated the venture capital variables, but not at a statistically significant level. We also note that *R&D* and *R&D ratio* are negatively associated, indicating that high levels of public investment in R&D are associated with a lower overall regional level of R&D investment.

In contrast to the correlations presented in Chapter 5, *Ent* shows a strong positive association with *Fs*, *Deg*, *R&D*, and *Rest of sectors*. However, we note that the association between *Ent* and *Biopharma* is weak. This suggests that general entrepreneurial activity in a region is not strongly associated with biopharmaceutical investment (either by count or value of deals), whereas investment in non-biopharmaceuticals is correlated with entrepreneurial activity. A final observation regarding *Ent* is that it is strongly correlated with *Claim*, satisfying a requirement for its use in the biopharmaceutical regressions as the instrumental variable for *Ent*.

The correlation results report a difference in the association of *Biopharma* and *Rest of sectors* with their respective *VC_public* series. For example *Rest of sectors* is negatively associated with public investment in the same sector group (*Rest VC_public*) but with relatively weak statistical significance, regardless of whether we use *VC_count* or *VC_value*. This result suggests that regions with high proportions of public investment in sectors non-biopharmaceuticals sectors will have lower levels of investment overall.

The variable *Biopharma* has a strong statistically significant and positive association with *Bio VC_public* in Table 6.8. It follows that regions with a high proportion of public deals in biopharmaceuticals will have a high number of deals. In Table 6.9 the association between these two variables is positive, but not statistically. Therefore according to the correlation results, the total amount of regional investment into biopharmaceuticals is not strongly associated with public contributions.

In summary, with the exception of *VC_public*, the correlation coefficients suggest that venture capital has a positive association with the independent variables. The correlation results also match the theoretical predictions shown in Table 6.1. The proportion of public venture capital investment was shown to have a positive association in *Biopharma*

investments, but a negative association for the *Rest of sectors*. This difference in association with public investment between sectors which was not expected. Finally, the ratio of public to private R&D was shown to have a statistically insignificant association with venture capital activity.

5.8.3 Estimation results

Tables 6.10 and 6.11 provide the results for the regression of the reduced form model using VC investment data by sector group. The results of the estimations are provided using fixed effect least squares estimation. Table 6.10 uses data from the VC_count series, Table 6.11 uses data from the VC_value series. However, we previously noted in section 6.2.2 that the diagnostic tests for estimating biopharmaceutical investment indicated that (a) the fixed effects estimation should be substituted for the panel least squares technique, and (b) that the presence of endogeneity in the *Biopharma* estimations indicates that two stage least squares estimation is appropriate. It logically follows that we should report estimates for *Biopharma* using panel least squares (panel OLS) and two stage panel least squares (panel TSLS), without fixed effects. The results of the OLS and TSLS regressions are given in Table 6.12. Therefore we concentrate our discussion of Table 6.10 and 6.11 on the results for *Rest of sectors* and *All deal* regressions. The results for *Biopharma* are included in Table 6.10 and 6.11 for completeness.

In the results tables summary statistics are provided for each regression. These include the adjusted R^2 value, the standard error of regression (S.E.reg), sum of squared residuals (SSR), the log likelihood (Logl'hood), Durbin Watson (DW) test for serial correlation, Akaike and Schwarz information criterion (lower values show best fit), and F-statistic for the joint significance of variables included. The statistical significance for the presence of endogeneity in *Ent* and the results of fixed effects significance tests are included in each table for clarity.

The regression summary statistics in both Table 6.10 and 6.11 show that the best fit to the model is found using *Rest of sectors* in the deal count model, or the *All deal* model for the deal value. Not surprisingly these regression models have stronger F-statistics, lower sum of squared residuals and better model selection criteria than the regressions based on *Biopharma*.

Table 6.10 Dependent variable: Deal count, fixed effect regressions

Fixed effect	Bio/pharma			Rest			All deals		
Variable	β	Std. Error	Sig	Coefficient	Std. Error	Sig	Coefficient	Std. Error	Sig
Const	0.44	1.39		1.56	1.00		0.91	0.81	
Ent	-27.78	11.52	**	8.04	8.12		2.24	5.39	
FS	10.19	5.79	*	8.08	6.41		11.62	6.53	*
Deg	-1.30	14.26		-1.61	5.69		-0.70	3.50	
R&D	2.27	2.74		-0.75	0.43	*	-0.12	0.80	
R&D ratio	1.03	0.77		-0.73	0.36	**	-0.27	0.22	
VC_public	1.09	0.56	*	2.01	0.66	***	1.37	0.43	***
Fixed effect sig.			N/S			***			***
Endogeneity			N/S			N/S			N/S
Adjusted R-squared	0.76			0.93			0.93		
S.E. of regression	0.51			0.23			0.23		
SSR	7.73			1.59			1.61		
Logl'hood	-24.29			13.73			13.34		
DW	2.28			2.58			2.67		
Akaike info criterion	1.76			0.18			0.19		
Schwarz criterion	2.46			0.88			0.90		
F-statistic	9.64			39.60			39.70		

***1% confidence level, ** 5% confidence level, * 10% confidence level. n/s not significant

In terms of the influence of individual variables shown in Table 6.10, *Ent*, *Fs*, *R&D*, *R&D ratio* and *VC_public* are all shown to have a significant influence on the number of regional deals. However, the results also show that for example the influence of each variable is dependent on the measure of venture capital activity. Only *VC_public* has a consistent statistically significant influence across each of the three estimations shown. In contrast *Deg* is not shown to be significant in any estimation shown in Table 6.10. Similarly, the influence of *Ent* on *Rest of sectors* and *All deal* investment is positive, although not statistically significant.

Table 6.10 shows when *Rest of sectors* is used as the dependent variable, *R&D* and *R&D ratio* are both negative and statistically significant. This result suggests that 1% increase in R&D levels in a region would reduce the level of investment in the rest of sectors by 0.75%. The negative direction of *R&D ratio* would indicate that increasing private R&D activity would attract more investment. Although the influence of *R&D* and *R&D ratio* on *All deals* is shown to be in the same direction as *Rest of sectors*, the results are not statistically significant.

The most consistent result in Table 6.10 is the influence of *VC_public* on the regional deal count. The coefficient of *VC_public* was positive and statistically significant in all results. The results indicate that a 1% change in *VC_public* results in a 1-2% change in the number of regional investments.

Table 6.11 shows the results of the regressions using the deal value as the dependent variable. These results indicate that the regional fixed effects are significant in explaining the regional distribution of the value of investment into both *Biopharma* and *Rest of sector* models. However, our results for *Biopharma* also indicate the presence of endogeneity in association of regional investment with entrepreneurship, confirming that the most appropriate results for *Biopharma* are shown in Table 6.12.

Table 6.11 Dependent variable: Deal value, fixed effect regression

Fixed effect	Bio/pharma			Rest			All deals		
Variable	β	Std. Error	Sig	Coefficient	Std. Error	Sig	Coefficient	Std. Error	Sig
Const	14.23	7.95	*	10.49	3.29	***	10.46	3.12	***
Ent	-110.54	32.49	***	21.15	18.32		20.16	16.36	
FS	11.11	34.04		-4.35	21.68		-3.70	18.72	
Deg	-22.56	55.84		28.74	11.88	**	21.35	13.20	
R&D	2.89	11.50		-9.53	0.59	***	-7.83	0.83	***
R&D ratio	3.45	2.17		-1.17	1.26		-0.51	0.93	
VC_public	3.60	1.96	*	-3.90	4.26		-0.19	1.70	
Fixed effect sig.			*			***			***
Endogeneity			**			N/S			N/S
Adjusted R-squared	0.57			0.77			0.79		
S.E. of regression	2.64			0.82			0.80		
SSR	209.56			19.98			19.36		
Logl'hood	-103.48			-47.07			-46.32		
DW	2.41			2.56			2.45		
Akaike info criterion	5.06			2.71			2.68		
Schwarz criterion	5.76			3.41			3.38		
F-statistic	4.74			10.34			11.24		

***1% confidence level, ** 5% confidence level, * 10% confidence level. n/s not significant

In contrast to the results in Table 6.10, we find evidence for the statistical significance of *Ent*, *Deg*, *R&D* and *VC_public* in at least one of the estimation models, but no evidence for the significant influence of *Fs* or *R&D ratio*. The results in Table 6.11 show *R&D* is a significant influence on investment in *All deals* and *Rest of sectors*. A 1% increase in the level of regional R&D per head of the population results in approximately an 8-10 % decrease in the amount of investment. Interestingly, the affect of *R&D* and *R&D ratio*, in Table 6.11, show a similar direction of influence to those discussed in Table 6.10. However, *R&D ratio* is not a statistically significant influence on the value of regional investment.

The results in Tables 6.10 and 6.11 show differences between the influence of the regional variables on the count of deals and value of venture capital investment. In contrast to the results produced from modelling the number of deals, Table 6.11 shows evidence that *Deg* is important for determining the value of deals. *Deg* has a significant positive influence on the value of *Rest of sectors* investment. Another difference between the results in Table 6.10 and Table 6.11 is that *VC_public* is only found to be significant for the value of

Biopharma investment. In fact, in Table 6.11 we find the coefficients for *VC_public* in the *Rest of sector* and *All deal* model are negative, the opposite direction compared to the results in Table 6.10.

The regressions associated with Tables 6.10 and 6.11 also produce values of the fixed effects for each region. These are given as deviations from the average constant value (*Const*). We summarise the value of the regional fixed effect coefficients for Tables 6.10 and 6.11 in the appendix. Evaluating the value of the regional fixed effects for the *Rest of sectors* and *All deal* models, consistently shows the Eastern, South Eastern and Scottish regions have the largest positive deviation from the average constant value. In contrast, the largest negative deviations for the count data are associated with regions such as Wales and Northern Ireland, or Yorkshire and the East Midlands based on the value of investment.

In this final part of the results section we concentrate on the *Biopharma* estimation results shown in Table 6.12. Overall, the results for *Biopharma* in Table 6.12 are consistent with the *Biopharma* results in Table 6.10 and 6.11, in terms of the direction of influence of the independent variables. We also find the coefficient for *VC_public* is positive and statistically significant, in agreement with previous results. However, we find the magnitude and statistical significance of the coefficients change as a result using the appropriate estimation technique.

Table 6.12 Results of two stage least squares models for *Biopharma*

Estimation	Least squares						Two stage least squares					
Model:	Count			Value			Count			Value		
Variable	β	Std. Error	Sig	β	Std. Error	Sig	β	Std. Error	Sig	β	Std. Error	Sig
Const	-0.13	0.54		-0.51	3.07		3.65	4.24		8.54	17.86	
Ent	-29.00	11.09	**	-99.10	47.20	**	-94.17	71.57		-255.35	289.66	
FS	11.12	3.18	***	45.84	18.81	**	33.16	24.27		98.93	94.61	
Deg	-13.86	2.75	***	-52.04	20.02	**	-27.81	15.47	*	-85.78	62.55	
R&D	5.31	0.21	***	17.96	2.34	***	4.16	1.47	***	15.13	6.32	**
R&D ratio	2.53	0.19	***	10.37	1.90	***	2.55	0.18	***	10.36	1.73	***
VC_public	1.54	0.36	***	4.47	2.55	*	1.44	0.43	***	4.55	2.04	**
Endogeneity	*			N/S			n/a			n/a		
Adjusted R-squared	0.73			0.48			0.58			0.42		
S.E. of regression	0.53			2.92			0.67			3.08		
SSR	11.57			350.17			18.17			388.17		
Loglikelihood	-33.96			-115.80			n/a			n/a		
DW	1.80			1.60			1.91			1.63		
Akaike info criterion	1.71			5.12			n/a			n/a		
Schwarz criterion	1.98			5.39			n/a			n/a		
F-statistic	22.69		***	8.24		***	24.97		***	8.26		***
Instrument rank	n/a			n/a			7.00			7.00		
Second stage SSR	n/a			n/a			10.74			349.57		

***1% confidence level, ** 5% confidence level, * 10% confidence level. n/s = not significant. n/a = not applicable.

Although the panel OLS results in Table 6.12 indicate a strong statistical significance of all the independent variables, we must take into account the presence of endogeneity in the

estimation of the model using the count of biopharmaceutical deals. Similarly, as previous estimations in Table 6.11 suggested the presence of endogeneity in the estimation of the model using biopharmaceutical deal value, there is reasonable suspicion of bias in the panel OLS results. Therefore, given the persistent presence of endogeneity in the estimations based on *Biopharma* series, we concentrate our analysis on the TSLS results for Biopharma and compared to the results shown in Table 6.10 and 6.11.

Table 6.12 shows several important differences to the results in Tables 6.10 and 6.11. We find that *R&D* and *R&D ratio* are statistically significant influencers of biopharmaceutical investment activity, by deal count and value of investment. These results indicate that either an increase in regional R&D funding, or an increase in the level of public R&D funding, would have a positive influence on biopharmaceutical investment activity in the reduced form equation.

Although the negative direction of influence of *Ent* is consistent across all results in this chapter, we find no statistical significance of *Ent* in the TSLS results. Similarly, we find that the regional concentration of financial services activity (*FS*) is not a predictor of biopharmaceutical investment. However, the TSLS results in Table 6.12 show *Deg* is a statistically significant negative influence on the count of biopharmaceutical deals.

The results in Table 6.12 also confirm variation according to technology sector in the direction of influence of the independent variables. For example, comparing the results of *Biopharma* in Table 6.12 to those for the *Rest of sectors* and *All deal* results in Table 6.10 and 6.11, shows the different influence of *R&D* and *R&D ratio* on *Biopharma* compared to the *Rest of sectors* and *All deal* regressions. Likewise, we find further differences between biopharmaceutical and non-biopharmaceutical activity associated with the influence of *Deg*. Interestingly, we find some consistency across biopharmaceutical and non-biopharmaceutical sectors, in terms of the direction of influence of *VC_public* on the number of investments.

5.8.4 Discussion and implication of empirical results

In this section we interpret our results by focusing on the first question presented in the thesis introduction. Specifically, this is to determine what factors affect the regional distribution of venture capital and secondly whether biotechnology investment is shown to be different from other sectors.

The results in section 6.3.3 indicate strong general support for the variables proposed in our venture capital model. We find that the summary statistics for each regression indicate support for the explanatory power of the independent variables. Individually each independent variable is also shown to be significant in at least one regression. As with Chapter 5 we find general support for the use of fixed effects estimation. This indicates the presence of unobserved regional effects. Over the period we evaluate, venture capital activity, in terms of the number of deals and value of investment, is tied to specific locations. This is shown to be a feature of early stage investment generally (*All deal*), and non-biopharmaceutical investment (*Rest of sectors*). The size of the fixed effects indicates this effect is largest in regions receiving the largest amount of investment, demonstrating the embedded nature of venture capital investment. However, we find in London, the region with the largest share of early stage investment activity, did not have the largest fixed effect coefficient. This result suggests that factors included in the model play a role in determining London's early stage investment activity.

As with Chapter 5, the fixed effects have the strongest statistical significance and larger coefficients when we evaluate the value of regional investment. This indicates that background regional effects, or regional endowments are important for determining which regions have high levels of funding. On the other hand, the flow of deals was not found to be as strongly regionally embedded. We find tests for regional fixed effects using the VC(count) data series are significant, suggesting the presence of unobserved effects, but their average coefficient value (*Const*) is not statistically significant in the regressions.

In contrast to Chapter 5 and our previous discussions, we find that investment in biopharmaceuticals is not strongly tied to regional fixed effects; the influence of regional specific factors on biopharmaceutical investment is weak or unsupported. For example, the number of regional biopharmaceutical deals is explained best by the independent variables used in the model. This is a clear difference between the organisation of biopharmaceutical investment and the results for other sectors shown in this chapter.

The *Biopharma* results indicate that investment in biopharmaceutical activity is organised according to the independent factors in the model, rather than specific regional endowments and historical associations with venture capital. This corresponds with our discussion of regional innovation systems and the literature reviewed in this chapter. Our results suggest that biopharmaceutical investment is the product of regional resources

which can be developed over time. The next step is to evaluate the influence of individual factors.

To understand the influence of individual factors we need to consider their affect on the supply or demand of investment. In section 6.2 we note that the coefficients in the results section are estimates of the reduced form equation coefficients. The reduced form coefficients include a scaling effect from the network coefficients in the structural form. . As in the previous chapter, in order to fully interpret our results we need to impose a restriction on the value of the network coefficients (α_3, β_5). In Chapter 5 our results indicated that an appropriate restriction was that, i) network effects exert a positive influence on supply and demand of venture capital, and ii) that the influence of networking was strongest on the supply side ($\alpha_3 > \beta_5$). Thus, the sign of coefficients for *Fs* and *VC_public* in our reduced form regressions results must be reversed (from negative to positive or vice versa) if we want to understand their influence in the structural form supply side equation (equation 2 in section 6.2.1). This restriction, in conjunction with Table 6.1, means we expect our regression results for the reduced form coefficients in section 6.3.3 to show *Fs* as negative coefficient, and the opposite sign to *Ent*, *Deg*, *R&D*, *R&D ratio* and *VC_public*

Our results suggest that some factors in the model do not influence venture capital according to our expectations. This is clearly the case because we find several factors in the *Biopharma* estimations frequently show the opposite influence to the *Rest of sectors* or *All deal* estimations. For example, we find the concentration of human capital (*Deg*) and R&D activity have a different direction of influence on *Biopharma* compared to non-biopharmaceutical investment activity. Likewise, although not statistically significant, the coefficient of entrepreneurship is shown to be negative in the biopharmaceutical results, but positive in all other results. These results support the view of variation due to activity in different sectors.

The coefficient of R&D is consistently negative for the *All deals* and *Rest of sectors* estimations and in the majority of cases is statistically significant. In contrast, the preferred results for *Biopharma* (shown in Table 6.12), indicate that R&D is significant and has a positive influence on investment activity. Applying our network restriction to these results confirms our expectation that regions with high levels of R&D generate demand for biotechnology venture capital investment. However, in the non- ... biopharmaceutical sectors, increasing regional R&D may have a detrimental influence on

the level of venture capital activity overall. This suggests, like in Chapter 3, that the bulk of venture capital investment is not directed towards high tech innovation, but flows to firms not associated with significant levels of R&D.

The results for the ratio of public to private R&D (*R&D ratio*) also support our analysis of biopharmaceutical investment. Table 6.12 clearly shows the coefficient of *R&D ratio* is positive and significant. Under our network assumptions this result indicates that increasing the level of public R&D investment increases demand for investment. This is in agreement with our expectation that biotechnology firms are closely linked to university research. We find that increasing R&D, particularly the public component of R&D, has positive implications for the strength of demand for venture capital from biotechnology opportunities. Although the demand for investment in non-biopharmaceutical sectors is not stimulated by increasing R&D activity, we find that increasing the private component of R&D is shown to be somewhat important for increasing the demand for investment from non-biopharmaceutical sectors.

The influence of the final demand side variable, *Deg*, also varies according to different sectors investment activity. The results also show that the concentration of professional workers is statistically of some influence on the level of venture capital activity. Applying the network restrictions indicate that increasing concentrations of professional workers negatively influences the number of biopharmaceutical deals, but encourages the amount of investment in non-biopharmaceutical sectors. We expected the concentration of professional workers to be a positive influence across both sectors. We find that regional demand for investment is generally increased by the concentration of degree qualified workers, but potentially at the expense of biopharmaceutical activity. For example regions with large concentrations of human capital may create a strong demand for investment from less specialist sectors. Given the risks of investing in sectors like biotechnology, the demand from non-specialist opportunities may appear more attractive to investors, and compete with demand from biotechnology firms.

On the supply side we find another difference to the results in Chapter 5. The results show that when the coefficient of *Fs* is statistically significant, it has a positive value. Our expectation under the network restriction described previously, is that the coefficient of *Fs* would be negative in the estimations, indicating that increasing the regional concentration of financial services would increase the supply of venture capital. Under the network restrictions we find that increasing financial services activity has the reverse effect.

One potential explanation for the influence of financial activity in our results is that during the period analysed, the general growth of UK financial services activity has not resulted in an increase in the supply of early stage investment. Our discussion of the literature in Chapter 2 suggests that in the post 2000 period venture capital funds for early stage investment have been impacted by the collapse of the Internet bubble. Our analysis reflects a decoupling of financial activity with early stage investment supply during the post 2000 period.

The other supply side variable in the analysis, *VC_public*, captures the influence of increasing the proportion of investment from Government on total investment. We find this variable consistently has a positive and significant influence on investment activity in the reduced form estimations, irrespective of sector. A positive coefficient value matches our expectations, given the restriction on the network coefficients. It indicates that regions with a high proportion of public finance are associated with lower levels of investment supply overall. This statistical finding can be interpreted in two ways. Firstly, that public investment has generally been targeted at areas with low supply. Secondly, as our coefficients are elasticity's, this also implies that increasing the proportion of public investment in a region has a detrimental influence on the overall supply. However, because of the limited period of analysis, it remains possible, that overtime, higher public funding may stimulate future private investment.

It follows that if public investment is used to increase venture capital supply, it must stimulate private supply as well, and not result in an increase to the proportion of investment from a public source. Here we find clear agreement with the literature. For example, the growth of venture capital in Israel is accredited to the successful use of public finance in seeding private funds (Avnimelech and Teubal, 2006). Our analysis supports the view that public investment in venture capital should be partnered with an appropriate private investor, preferably with specific experience in venture capital (Dossani and Desai, 2006).

5.9 Conclusion

In this chapter we have shown that early stage investment is concentrated into certain regions of the UK. We have also tested a model for explaining the regional variation of early stage venture capital activity in the UK, in terms of deals and value of investment, using measures of a region's entrepreneurial behaviour, financial, human and technological

capabilities. We have also examined the importance of public investment in the form of direct public venture capital and public R&D. The results have shown that these variables are relevant for explaining variations in regional levels of funding, although it is clear that the influence of specific variables differs between biopharmaceutical and other sectors.

This chapter also show several important aspects of biopharmaceutical venture capital activity. Firstly, regional trends in biopharmaceutical activity are different from those in other sectors. Biopharmaceuticals have been shown to be a regional priority in regions such as the East, but of lower prominence in London. Scottish biopharmaceutical firms outperform other sectors in the region in terms of the amount of finance received. We have seen variation in the role of public investment in regions, and observed the stronger reliance of biotechnology firms on Government finance.

Secondly, we have found that venture capital investment in biotechnology is more strongly associated with regional activity. In general early stage investment activity is strongly tied to specific regions and relates to long term regional factors. However, we find biotechnology investment is only weakly influenced by unobserved regional specific factors. Rather than being distributed according to historically embedded regional endowments, biopharmaceutical investment is responsive to changes in regional activity in agreement with our discussion of clustering and regional systems of innovation in Chapter 2. For example biopharmaceutical investment is influenced by the level of regional R&D, particularly from a public source. On the one hand this indicates the potential for influencing the regional distribution of venture capital activity, however, given the policy towards dispersed clustering this may reflect wider UK policy initiatives to promote basic University based research wherever located.

Thirdly, we find that UK policy can have a complementary role in encouraging venture capital activity, by targeting different areas of the economy. For example, investment in biotechnology shows distinctive patterns of influence from regional activities, such as R&D. This finding emphasises the application of sector targeted regional policy, which take account of variations in technology sector. We find strong evidence that policies directed towards supporting public investment in R&D encourage biopharmaceutical investment. The lack of impact of R&D investment on non-biopharmaceutical investment needs further evaluation; it appears that other sectors respond to concentration in private R&D activity, rather than the overall level of R&D investment. We also find that if public investment is directed towards venture capital directly, then this must be made in

partnership with the private sector. We find little support for increasing the proportion of public venture capital investment in a region. Our analysis indicates that policy should be designed to target specific sectors and be applied as a package of policies to support existing activities in the regional economy.

However, without a method to identify the scaling effect of network effects on the supply and demand of venture capital it is not possible to give a precise size of influence of the independent variables in the structural supply and demand form equations. We have consistently applied a restriction to the reduced form coefficients to help understand the influence of factors on the supply and demand for venture capital. Together with the importance of regional factors this suggests the structure of networks may play an important role in determining the regional distribution of venture capital and underpin regional advantage. Therefore, we continue our thesis by focusing on networking activity related to venture capital activity. We will return to these results in the final chapter this thesis to explore the implications of our assumptions regarding the influence of networks on investment activity.

6 Syndication networks

6.1 Introduction

As we have observed so far, the distribution of investment for small to medium sized enterprises (SME) in the UK, as elsewhere, is frequently concentrated into one or two key geographical areas which are anticipated as providing the most beneficial nurturing environment for start-up firms, often referred to as clusters. These environments are frequently described as being supported by access to local resources such as the core knowledge required to support the start up, experienced human capital, proximity of investors and the benefits of access to knowledge and information flowing around local informal networks (Florida and Kenney, 1988; Powell et al, 2002; Castilla et al, 2000). As venture capitalists also benefit from the flow of information regarding new opportunities and utilise networks to develop associations to improve the performance of their investments, it follows that an investor's ability to access new deals may decrease with distance from the investment opportunity (Sorenson and Stuart, 2001).

However, networks, particularly those based on syndication between investors (as described in Chapter 3), play an important role in overcoming the difficulties presented by the distance between investor and opportunity (Sorenson and Stuart, 2001; Kogut et al, 2005). As we have outlined in Chapters 2 and 3, networks are important activity in the venture capital industry. In agreement with social capital theory, venture capitalists form relationships with other investors to help to facilitate the transfer of information about investment opportunities, as well as develop long term trust between investors. By examining the structure of relationships formed through syndication we can understand the importance of actors, or groups of actors and their impact on the function of the structural social capital in the UK venture capital network.

The aim of this chapter is twofold. Firstly, to investigate whether we observe established patterns of syndication networks in the UK. Secondly to analyse the structure of these networks compared to the literature on other national VC networks and to investigate whether the characteristics of the networks vary according to sector. Thus, this chapter contributes towards answering our second thesis research question.

6.1.1 Structure of networks – the role of geography

Sorenson and Stuart (2001) call on a history of sociological research that draws out the importance of proximity in terms of physical and social space in creating social interaction. They suggest that increasing distances across either space, results in a lower probability of

forming relationships. In the world of US venture capital, which has been shown to thrive from informal connections and where economic activity is embedded in physical spaces, Sorenson and Stuart (2001) find that increasing distance between venture capitalist and a new target firm causes a decline in the likelihood of investment. This reflects the localised nature of VC activity, and the strong preferences for investing in their own local area and industry.

Several studies have shown that investors are co-located with their investments in the US, (Powell et al, 2002, Griffith et al, 2007) and often based nearby in the UK (Rosiello and Parris, 2008). Although Kenney and Patton (2004) suggest that some sectors such as biotechnology are less dependent on co-location. A preference to provide finance to local businesses means they also capture important information regarding the firm, entrepreneur and technology to reduce information asymmetries. Clearly, there is a debate about the location of individual investors, but what are the dynamics of syndication networks?

Sorenson and Stuart (2001) argue that investors who have a central position in the syndication network can reach more distant opportunities by using their relationships with other investors to identify and evaluate new opportunities. The authors find that central investors receive invitations to syndicate in opportunities from other VC's looking to attract the reputation of established investors. If the VCs are in different geographies the resulting syndication can create long distance relationships. The likelihood of a long distance investment is increased if they participate in a syndicate containing a prior affiliate, where that affiliate is local to the deal.

“VC firms with a history of provincial investment patterns and those without central positions in the industry’s co-investment network tend to invest locally; those who have established many and dispersed relationships with other VC firms invest across geographic and industrial spaces more frequently.” (Sorenson and Stuart, 2001. p.1584)

In general Stuart and Sorenson (2001) believe that the syndication network provides an institutional structure that allows the “expansion of the spatial range of exchange in markets that rely on private information or a high degree of trust for transactions to occur” p.1584. Their research also emphasises the importance for a firm to have connections to locally based investors. A firm hoping to obtain funding in a region without locally based VC community with some experience may find it difficult to gain access to the wider networks (Sorenson and Stuart, 2001).

Kogut et al's (2005) research finds that a giant network component quickly develops in their models of venture capital syndication. This component provides full geographical coverage of the US. Therefore, despite the emphasis on local ties, the syndication network operates on a national basis. This giant component is a distinctive characteristic of the venture capital industry. At the centre of the giant component Kogut et al (2005) find experienced investors whose names are synonymous with venture capital. These investors operate nationally and repeatedly syndicate with other nationally orientated investors, in preference to searching out new entrants to expand their network of ties. In this way established investors at the centre of the network acts as 'spanners across geographies', by building trust based relationships with other established investors in different locations.

Syndicates can be viewed as the building blocks of larger venture capital networks, as without the co-ordination of syndicates, venture capitalists would invest alone, and the giant network component observed by Kogut et al (2005) would not arise. The rapid formation of a large network component is thought to be a distinctive form of organisation in the venture capital industry; such networks have implications for the overall success of the venture capital industry. Research on US syndicate networks has shown there to be a core group of repeatedly syndicating investors (Sorenson and Stuart, 2001). Bygrave (1987) found that from a sample of over 400 VC firms, a core of 61 investors was found in $\frac{3}{4}$ of the portfolio firms. This result suggests an extensive network was formed around these central investors. Bygrave (1988) also finds that relationships between investors were particularly dense in hi-tech investments. In hi-tech investments the need to gather information to reduce uncertainty is highest; as a result the networks were tighter with denser linkages.

As we discussed in Chapter 3, the distribution of relationships between agents in a network can indicate important network properties. Kogut et al (2005) find that the best 'fit' to the degree distribution¹⁷ of investors in their syndication networks, followed a power law. However this was a poor fit. At the extremes of the US investor degree distribution the numbers of investors with few connections were too high and a small minority of investors had too many connections to give the right fit. They rule out preferential attachment as a means of expanding the network, particularly as they find that highly connected investors prefer other highly connected investors, as opposed to generating new connections.

¹⁷ Definition of degree centrality given in chapter 3.

6.1.2 The role of network development

Investors must balance their preference for repeating ties with familiar partners, by obtaining access to new opportunities. In order to access new opportunities and diversify their portfolio they must form new relationships with relatively new entrants. For example new investors may enter the industry because of their expertise in an emerging technology. In this case the new investor is a specialist, so may have a competitive advantage over more established investors who are less familiar with the new technology. To form a relationship with a new entrant, incumbents tend to invest in opportunities where at least one syndicate member is known from a previous deal; thus reducing the risk of entering into deals with unknown syndicate partners (Kogut et al, 2005)

Overtime, reciprocation between investors is expected to develop strong patterns of syndication. Given an established investor's aversion to syndicating with an unknown investor, Hochberg et al (2007) suggest strong relationships between investors may act as a barrier to entry for other local investors. This may prevent smaller locally based investors from gaining access to deals. In order to gain entry to the network local investors have to work to attract other established investors to participate in their deals.

Although we emphasise the informal social networking aspect of syndication networks, these discussions are also complemented by considering the financial risk motivation to syndication. The financial risk motivation to syndicate is driven by a desire to share the risk and financial burden of financing a particular company with other investors (Manigart et al, 2006). The financial risk motivation for syndication is explored in more detail in Chapter 8. However, the financial risk motivation suggests that from a network perspective we should expect strong repeated relationships to form between the largest investors. For example forming a relationship to a large investor is likely to have a greater value for the other partner. The larger the investor the greater the ability to share the financial risk, and the greater the opportunity to obtain reciprocation on future deals. It logically follows that a large investor should choose to network with other large established partners who are able to share the risks of investing. This maintains close relationships with those investors who are most likely to co-ordinate the network and reciprocate with access to their own investment portfolio.

Following the logic of the financial risk motivation larger investors should only network with smaller investors to gain access to new opportunities, which may have previously been perceived as too risky or difficult to assess their potential. The alternative motivation

of investor syndication to add value is expected to create relationships between investors based on particular skills or expertise. In this case we would expect that biopharmaceutical deals would develop a sub-set of investors able to provide the relevant sectoral guidance to the firm. We continue these discussions of motivations to syndicate in Chapter 8.

6.1.3 Performance

The centrality of investors in the network has been shown to increase the performance of their fund, portfolio exits and firm survival (Hochberg et al, 2005, 2007). Hochberg et al (2007) find that after controlling for factors known to determine VC performance, that the position of VC's within a syndication network was important for both fund and individual portfolio firm performance. Well networked VC's with central positions in the network were linked with more exits and trade sales, and also connected to improved survival of portfolio firms. The connectivity benefits were highest for those VC's connected to other 'well connected VC's. Strongly linked investors were expected to have greater control over cooperating, which explains why Hochberg et al (2007) found deal valuations to be positively linked to measures of the network size. In their analysis accounting for network measures reduced the importance of the experience of VC's on performance.

Although Sorenson and Stuart (2001) make no comment on the implications of network ties for the profitability of an investor, it follows that we can bring together their findings on the geography of investment with the work of Hockberg et al (2005, 2007). For example, Sorenson and Stuart (2001) find that older more established investors with central network positions are able to invest over larger distances than younger less experienced peripheral investors. In light of Hockberg (2005, 2007) we would also anticipate that investors with greater geographical access to deals, will have a larger choice of deals and therefore have better access to high quality opportunities regardless of location.

6.1.4 Some conjectures about VC syndication networks in the UK

Based on the literature we can expect investors in SME to be situated in a network of past and present affiliations with other investors, which potentially influences their access to future deals. The function of these networks is partly to share information about investment opportunities, but also, as suggested in the syndication literature, is to share access to deals with the expectation that this will be reciprocated. The co-ordination of the network is based on familiarity and trust.

Therefore in terms of network structure we expect the main co-ordinators of UK syndication networks to be a minority group. As in Kogut et al (2005) we expect the distribution of relationships for each investor to approximately follow a power law. We also expect this general trend to hold across different sectors. However, sector networks are expected to be different. In line with Bygrave (1988) high uncertainty associated with hi-tech sectors, such as biopharmaceuticals, will lead to relatively dense network structures compared to low-tech sectors. Similarly, hi-tech sector network will have a higher proportion of strong or repeated relationships between investors.

The overall network will have a giant network structure which includes the majority of investors, organised around a core of central investors. As Kogut et al (2005) stress that new technologies involve specialist investors, we might also expect that the central structure of the network is different across sectors. We expect that the importance or centrality of investors in a network may change according to sector.

In the giant network structure we expect that the established names of venture capital to play the key co-ordinating role. Established names of UK venture capital will operate on (i) on a national basis; (ii) at the centre of the network, (iii) connected by strong repeated and dense linkages. (iv) building on the expectation that established investors will act as the co-ordinators of the network, they will provide the links between different geographical pockets of activity. It follows that experienced actors have the ability to run multiple offices, as well as invest outside of their own locality using their wider network of contacts to support their investments. Therefore established investors will control connections of local investors to the main component.

We expect that local investors will be (i) smaller in size (ii) being locally constrained, will be strongly connected to other smaller local investors, so dense patterns of linkages should be observed where local investors syndicate together on local opportunities. (iii) Finally because of difficulties in attracting large investors only some groups of local investors will be joined to the main network component through connections to national investors. Therefore we expect that peripheral areas of the network will be characterised by small groups of strongly inter-connected small investors. We expect to be able to associate these smaller groups with specific UK regions.

The combination of position and strength of relational ties of the established investors provides further benefits in the form of control, firstly through their influence on using the

network to improve the performance of their own portfolio, but also in terms of the formation or expansion of the wider network through weaker less frequent linkages with new entrant investors. The network grows either by entrants allowing established investors to invest in their deals or where new entrants follow established investors into deals in later stages. In both cases the position of the established investors provides some control over how new entrants can profit from the benefits of association with the high performing central investors as found by Hochburg et al (2007). Therefore, we can envisage two different types of new entrants – a small local investor looking to syndicate with established players to improve their investment performance, or larger institutional or general investors looking to invest in opportunities with an established performance profile and therefore of a more acceptable risk. The latter group could also include large corporate companies investing with ambition to acquire the firm at a later stage.

6.1.5 Analysis of networks

We have used the literature to generate a number of expectations regarding the role and structure of syndication networks. In the following sections we will compare the structure of networks observed in the UK to these expectations. This is pertinent because despite literature discussing the different motivations of syndication in the UK compared to the US literature, the network literature makes few references to the UK specifically. We also note the lack of significant discussion of networking as a sector specific activity, or investor specialisation. Therefore we will explore how these expectations fit with our UK data and investigate differences according to sector and region.

6.2 *Method and approach*

6.2.1 Relational data

In this chapter we use the Library House database of early stage investment deals to provide the information on each firm, the amount of investment received, and the names of different investors in each round. In some cases the data available on the investors in a round will provide the fund name. Using the Internet, and the membership details of trade associations, such as the BVCA we drafted a list of all investors active in the UK, and used this to determine the names of active investors. In the cases where the named investor in the data did not appear on our list we used the Internet to find the name of the fund manager.

During these searches we also encountered cases where a fund is administered through one agent, but the investment managed through a second party. In these cases we take the details of the named managing investor, rather than the specific fund. We cannot rule out

that there are some 'fund of fund' type arrangements, particularly where large investors have seeded a small start-up venture capital firm. These types of relationships are not included in our analysis, as we are interested in understanding the relationships between the active investor as opposed to the financing source. We also make the assumption that the finance provided is venture capital investment, i.e. with the intention of creating a new business as opposed to any other motivation for creating a new entity, such as control of IP, or other competitive reasons.

Finally, in some cases only the type of funding is indicated, for example, University Challenge fund, institutional investors. Where these investments could not be traced they are removed from the analysis, as they create 'false' linkages if they remain in the data.

6.2.2 Network representation and analysis: affiliation and co-investment syndicates

In the process of analysing the data for this chapter we used several different types of network representations, including one mode (investor only) and two mode (investor and firm) representations. As our main aim is to analyse the relationships between investors we report the results for the one mode network only. We will also manipulate the relationships to show strong relationships (relationships that occur between network actors more than once) and also to reduce the network to show only those actors who provide links in the network and so decide the network structure.

In addition to the data being comprised of two modes, we use two definitions of syndication to construct the relationships in the network (Brander et al, 2002). The first is a wide definition of syndication, based on the shared affiliation of investors to the same firm. In the mode 1 network representation of an affiliation network a line between two investors indicates that they share an affiliation to at least one firm. In interpreting this network there is an implicit assumption, that because these investors both provide finance to the firm, at some point, there is a connection between investors although not necessarily a formal relationship. Clearly in cases where there are multiple common affiliations it is likely that there is a strong relationship between investors, and we can assume that this relationship will involve the transfer of information about opportunities and repeated relationships suggest the development of trust. However, it does not necessarily mean that they co-invested together at the same time.

The alternative definition of a syndicate is based on co-investment. In a co-investment network we introduce the restriction that a relationship between investors only exists if

investors have provided finance to the same firm at the same time. This is a more formal relationship. As a firm may receive multiple rounds, often from the same group of investors, the same firm may appear several times in the dataset. In this case we just look at relationships between co-investors, and the details of the firm receiving the investment is of less importance. The co-investment networks are expected to be more fragmented and provide a more formal view of relationships between investors formed only when investments occur between investors in the same firm at the same time.

We can then compare how these two representations of syndication networks differ. A large difference would indicate that investors use different networks for obtaining information compared to the relationships they build through investing with other investors. In all network examples described in this chapter no distinction is made when drawing the networks as to which period individual investments relate. The network represents investors with a common affiliation to particular firms. It is possible to identify the affiliation of these investors across several firms.

As we only show the network formed from the cumulative activity of investors in our dataset, we concentrate our analysis to examine the expectations generated from the literature for the structure of the network, rather than how the network may evolves or the performance outcome of the network structure. Based on our discussion we categorise our expectations and propose a method of evaluating these expectations.

Table 7.1 Expectations for the structure of UK investor networks

Category	Expectations	Method
Structure	Network to include a single large component comprised of established national investors	Visual inspection of sociograms and network statistics
	Established investors to have the most central positions; smaller investors in peripheral positions	Use of centrality statistics to indicate most central investors and visual inspection of sociograms
	Ties between central investors to be strong (repeated)	Modification of sociograms to exclude weaker ties- count of repeated ties
	Ties between smaller local investors to be strong (repeated).	Modification of sociograms to exclude weaker ties- count of repeated ties
	Smaller local groups will be connected to the main component through ties to national investors	Visual inspection of sociograms
Geography	Strength of ties between investors to indicate different regional clusters.	Applying categories to the vertices of the sociogram according to geography
Sector	Network density to be higher in more technological uncertain sectors	Network statistics
	Centrality of investors will vary across sectors of activity	Correlation of centrality measures across sectors

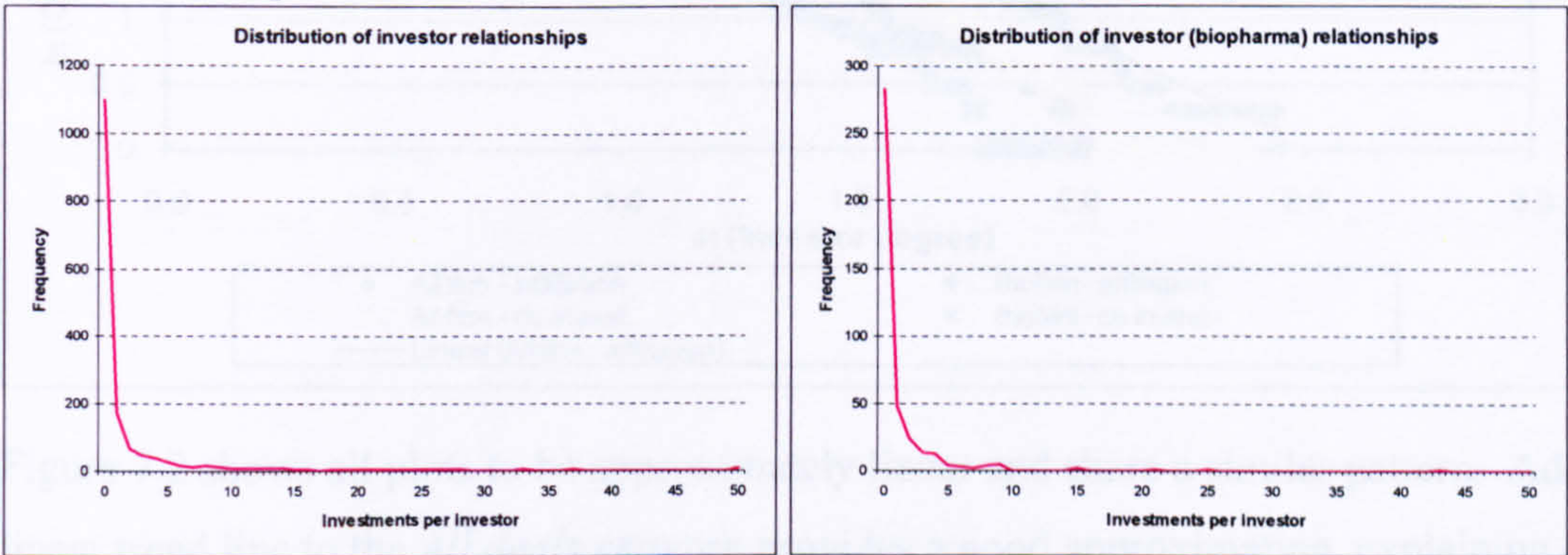
In the first instance we examine some general properties of the network, including the distribution of relationships between investors based on affiliation and co-investment networks. Then we use network statistics to examine whether the networks are organised differently according to sector, before examining the centralities of investors according to sector according to our sector level expectations. This helps to understand whether we should view the full network as a single network, or an aggregation of different sectors. Finally we examine the expectations for the detailed structure and geography of the network using network various representations – sociograms, to show different types of network structure and activity. We use network analysis software called Pajek to analyse our network and report network statistics and sociograms.

6.3 Network analysis

6.3.1 Skewed distribution of relationships

We find that the majority of investment activity is concentrated to a minority of investors, relative to the total active pool of investors. Approximately 90% of all investors make five or less investments, and this trend holds regardless of whether we consider all investments, only biopharmaceutical investments or investments at a regional level. When we graph the number of investments held by each investor we find the distributions have extended non-continuous tails with a small minority of investors with particularly large number of investments, as shown in Figure 7.1

Figure 7.1 Graph of the distribution of investor relationships with portfolio firms



We find approximately 70% of investors are affiliated to only one firm. Of these, 4% involve no syndicate (i.e. one investor per firm) and so are isolated from the network in terms of co-investment and shared affiliations to other investors. This description of the data suggests that a feature of investment activity in the UK is the diversity of involvement; as shown by the combination of a minority of investors with large portfolios, and a majority who participate infrequently. A similar pattern is found for the biopharmaceutical sector.

In line with Kogut et al (2005) we also examine the measure of the degree of each venture capitalist. As we find our degree distribution is non-continuous we follow Kogut et al (2005) and use cumulative frequency graphs and remove vertices with degree equal to zero. To check for the presence of a strong power law relationship we use a log-log plot. As we examine the network as a static structure, a linear relationship in the log-log plots is suggestive of a structure containing hubs.

In Figure 7.2 below, we show four log-log cumulative frequency graph for investor degree centrality based on the 1-mode network. Following Newman (2005) we plot the cumulative degree distribution to evaluate our data for the presence of hubs. We show plots from the *Biopharma* and *All deals* data, using statistics based on the affiliation and co-investment networks.

Figure 7.2 Graph of log-log plot of cumulative frequency of investor degree

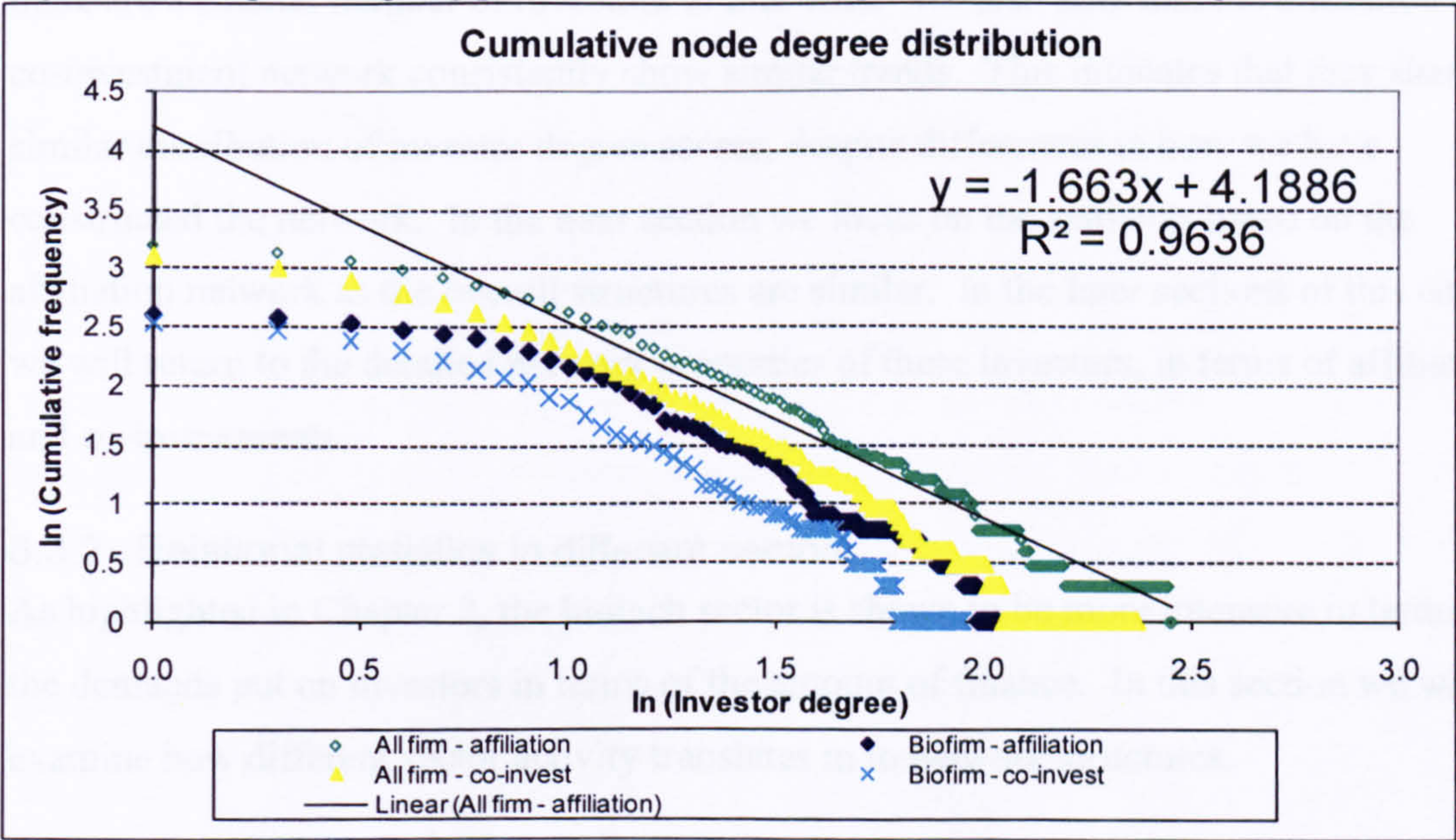


Figure 7.2 shows all plots to be approximately linear and share a similar pattern. Adding a linear trend line to the *All deals* network provides a good approximation, explaining around 97% of the variation. So we find that the power law relationship is a strong fit. In agreement with the observations of Newman (2005) regarding networks and power laws, the linear trend is strongest in the tail of the distribution. However, to be sure of the presence of a power law the data needs to be evaluated over a range of four orders of magnitude (Newman , 2005). Our distribution of degree statistics only includes three orders of magnitude. Similarly, Barabási and Albert (1999) suggest that the gradient of the

linear trend should have a magnitude in the range 2.1 to 4, to indicate preferential attachment. The gradient of the trend line shown in Figure 7.2 is outside this range.

Whilst we find that the presence of extremely high degree investors in each network is indicative of a linear trend and the presence of hubs, like Kogut et al (2005), we find evidence that the hub and spoke type structure is not a good model to apply to this network. For example, in order to fit the Barabási and Albert (1999) criteria, the trend line would need to be much steeper. This indicates that in our results, we either observe too small a minority of investors with high degree statistics relative to population of investors; or alternatively, given the size of our population, we observe a minority of investors with a much bigger degree statistic than would be expected.

Finally, as the investors in the biopharmaceutical network are a subset of the investors in the main network, it follows that their cumulative frequency degrees scores are lower, as there are a smaller number of investors to link with. We also note that the affiliation and co-investment network consistently show similar trends. This indicates that they share a similar distribution of investor degree scores, despite differences in how we have constructed the network. In the next section we focus on the statistics based on the affiliation network as the overall structures are similar. In the later sections of this chapter we will return to the detailed network properties of these investors, in terms of affiliations and co-investments.

6.3.2 Relational statistics in different sectors

As highlighted in Chapter 2, the biotech sector is shown to be more intensive in terms of the demands put on investors in terms of the amount of finance. In this section we will examine how different sector activity translates in to network structures.

Table 7.2 compares the characteristics of affiliation networks across sectors. To do this we consider the network in 1 mode form, specifically looking at the shared affiliations between investors. Each sector is defined according to the firm receiving the investment, thereby creating a network of investors with interests in a particular sector. Table 7.2 shows the number of vertices and edges in each 1 mode sector network. A vertex in this chapter refers to an investor; an edge refers to the connection between two investors. We consider each edge to be undirected, and can have an integer value greater than zero. Edges of value greater than one refer to multiple ties between investors (i.e. repeated affiliations between two investors). The second part of the table shows the density of the

each network. The density is defined according to the ratio of count of actual ties in the 1 mode network, to the count of all possible ties if each investor was connected to all other investors. As the density statistic is sensitive to network size (and higher numbers of vertices tend to decrease network densities) this makes it difficult to compare densities across networks. We follow De Nooy et al (2005) and include average degree statistics to understand the relative cohesion of different networks. The table shows the average degree¹⁸ value in terms of the mean and median. The density of a network is generally specific to the size of a network; the mean and median degrees are measures of the density of relationships between investors which can be compared across different sized networks.

Table 7.2 Investor network statistics by sector

Sector	Total network				Density		
	Vertices	Edges (any value)	Edges valued >1	% multiple	Density	Mean degree	Median degree
Comms	329	798	15	1.9%	0.015	4.85	4
Biopharma	402	2071	153	7.4%	0.026	10.30	7
Healthcare	192	438	20	4.6%	0.024	4.56	3
IT	743	2657	149	5.6%	0.010	7.15	4
Other	643	1564	79	5.1%	0.008	4.86	3
All	1585	6980	589	8.4%	0.006	8.81	5

The table shows the total network includes 1585 different investors, sharing nearly 7,000 relationships to the same portfolio firms. Of these 7,000 relationships 589 (8.4%) are repeated on more than one occasion. This means that investors have more than one shared affiliation in nearly 600 of the relationships. We note that for the entire network approximately 0.6% of all potential relationships are found, given by the density statistic. The final row of Table 7.2 shows that for the total network, on average each investor has a minimum of 8 ties based on the mean degree score, and 5 ties based on the median degree value¹⁹.

When we look at the sector network statistics we find that nearly half of all investors in the database have made an IT investment (47%), compared to 25% of investors into biopharma. The number of investors active in IT is 1.8 times the number of investors active in biopharma. Yet in terms of relationships, IT has only 1.3 times the number of relationships of biopharma. Similarly in the second largest sector network, categorised as ‘Other’, the

¹⁸ The average degree is the simple calculation of the sum of the degrees of each investor divided by the number of investors in the network. This measure counts multiple ties as one relationship.
¹⁹ As the degree measure is an ego centric score, a relationship between investors A and B, counts towards the degree score of A and B. Therefore multiplying the average score by the number of investors does not equal the number of relationships, and is an average with respect to each investor.

number of relationships are fewer than in the biopharma network. Thus, Table 7.2 shows that the biopharma network consistently has higher density measures than other sectors.

Finally, the statistics for the proportion of multiple relationships indicates that biopharma has a relatively high proportion of investors who repeatedly fund the same firms, compared to the other sectors. Although biopharma investors are not the largest group, we find that they have greater and stronger connections to each other through common affiliations than compared to the other sectors.

6.3.3 Summary

In summary this analysis shows that there are relatively few investors who have made more than five investments and a high proportion of investors are only affiliated to one firm. However, we still find an extensive network is formed through common affiliations between investors, suggesting that the majority of investors have a tie to another investor. A minority have a vast number of ties.

We also find evidence of repeated affiliations between investors. This suggests that relationships between investors also vary in strength. In general the majority of relationships are weak, with affiliations occurring only once. Those investors tied with repeated ‘strong’ relationships occur most frequently in the group of biopharma investors.

6.4 Network structure

In this section, using a variety of statistics, we will look in more detail at the structure of the core of the networks discussed in the previous section. The first statistic we look at is the size of the core component²⁰ and its size relative to the total pool of investors. The size of the core component indicates how many investors are connected (directly and indirectly) to the central investors. The percentage of investors connected to the core component indicates how coordinated the network is, or alternatively how fragmented the network is. If the number of investors in the largest component is low it suggests the presence of several different networks, rather than the single large component as found in US syndication networks.

We also measure the average distance between vertices. The average distance provides an indication of how information could travel through the network, as high values indicate that information has on average to travel further between different actors in the network.

²⁰ By core component we refer to the largest connected group of investors

The average distance between vertices is calculated by taking an average of all geodesics²¹ from one vertex to another in the network. As we exclude pairs that are unreachable, this measure refers to the distance between vertices in the core component.

In order to evaluate how the network is structured it would be useful to describe the network in terms of centrality. Firstly we discuss how the network is organised in terms of general structure of the network and whether it is organised around key co-ordinators who operate at the centre of the network (centralization), and secondly to know who the most central actors are (centrality of investors) (De Nooy et al ,2005).

To measure centrality we have three different calculations, from which we can generate network centralizations. A direct measure of centrality uses the degree of each vertex, as central actors will have larger numbers of relationships. We measure the degree centralization of a network as “the variation in the degrees of vertices divided by the maximum degree variations which is possible in a network of the same size” p.126 (de Nooy et al, 2005).

The alternative measures of centrality include indirect links between actors to calculate centrality. The first is betweenness centrality, which perceives central actors as intermediaries between other actors in the network. Therefore the measure of betweenness centralization, “is the variation in betweenness centrality of vertices divided by the maximum variation in betweenness centrality scores possible in a network of the same size” p.131, where the betweenness centrality for a single vertex is expressed as a proportion of “all geodesics between pairs of other vertices that include this vertex” (de Nooy et al, 2005 p.131).

The second measure of indirect centrality uses the distance between a vertex and all other vertices, with the assumption that actors who are close to other actors will have more central positions. As with other measures, the closeness centralization is the, “variation in the closeness centrality of vertices divided by the maximum variation in closeness centrality scores possible in a network of the same size” (de Nooy et al, 2005 p.127). As this centralization is based on geodesic distance, the score is based on the core component vertices only.

²¹ Geodesics are the shortest path length between two vertices

A common feature of these three measures is that they compare networks to the most central structure of a network which is based on 'star' type configurations. In a star type network a single central actor is directly connected to all other actors. This centralised structure facilitates efficient transfer of information to the other actors in the network. From a degree centrality perspective, the central actor is tied to all others, from a closeness perspective this minimises distances between network actors. In both cases this structure optimises how easily information can reach all the network actors. From a betweenness centrality perspective, the central actor is the link between all other actors, therefore this is the optimum structure for an intermediary or a controller (De Nooy et al ,2005). In all cases the higher the centrality score, the greater the contrast between the centre and the periphery of the network.

However, we can anticipate two potential drawbacks in using centrality measures for this analysis when we think about our discussion of networks in Chapter 3. At one level we view the relationships between investors based on sharing information and building trust. From the information sharing perspective, in large networks the central actors could potentially operate as a bottleneck if all information is transferred and accessed through a single actor and may result in some inefficiency.

If we think about the relationships as about sharing risk, then assumptions regarding the efficient transfer of information may not hold. For example a high network centrality score would suggest a small group of investors share a large burden of risk in a particularly industry. Taking both points together indicates that the optimum network structure for venture capital investing may not always be the most centralized and might indicate the presence of small world type structures. However, the literature does indicate that centrality will be a feature of the networks if they are managed by the established national investors.

Our goal here is to use the centrality measures to understand whether different sectors have more centralised network structures and to highlight the presence of central investors in co-ordinating the network. To achieve this we report in Table 7.3: the number of vertices in the largest component, the proportion of investors in the core compared to the total network, the average distance between investors, and the three network centralization scores. We compare these measures across the sectors to understand how network structures may vary.

The table shows that the total network of all investors demonstrates a strong presence of a single core component containing 90% of investors. In contrast to our earlier findings that a large number of investors only invest occasionally, the majority of these investors do have an affiliation to other investors that join them to the centre of the network.

In the individual sector networks the percentage of investors connected to the core are lower. This suggests that some relationships between investors occur independently of sector classifications. By expressing the networks as sector based, some investors in sector networks appear isolated from the core of that particular sector network. For example an investor may participate in more than one sector and so have relationships which do not feature in a given sector network. As we aim to capture sector specific characteristics this is not a problem.

Table 7.3 Network statistics by sector

Sector				Centrality measures		
	Vertices in Core component	% of total vertices	Ave. distance between vertices	Degree	Between-ness	Close-ness
Comms	202	61%	3.56	0.10	0.105	0.31
Biopharma	359	89%	2.84	0.24	0.234	0.36
Healthcare	149	78%	3.15	0.26	0.344	0.43
IT	623	84%	3.36	0.18	0.269	0.43
Other	484	75%	3.68	0.16	0.262	0.40
All	1423	90%	3.31	0.17	0.191	0.38

The table shows variation in the proportion of investors involved in the network core across different sectors. Biopharma has the largest network core relative to the pool of active investors, with 89% of investors connected to the main component. In contrast, investors in communications are more fragmented with only 61% of investors connected to the main component. We find that the investors in the main component in biopharma are the most closely connected, on average being only 2.84 vertices apart. It suggests that information can be transferred from one investor to any other investor on average through 3 investors in biopharma, compared to 4 investors in the other sectors.

The results of the centrality analysis suggest that the biopharma network is less dependent on central investors compared to the other sectors. The centrality scores measure the variation in centrality of individual investors. A low variation in scores translates into a more distributed network structure. In terms of direct centrality (degree), biopharma is ranked second after the healthcare sector, but in the indirect measures biopharma performs

relatively poorly, with a low centrality in terms of betweenness and closeness, relative to other sectors such as IT, Healthcare and 'Other' types of technology.

Interpreting these measures of centrality suggests that the UK biopharma network is formed of a relatively large and dense core component. The degree statistics indicate the presence of central actors, or hubs with many direct connections. The geodesic statistics indicate this sector has relatively short distances on average between each investor. Therefore we can view investors in this sector as generally well connected with few investors isolated from the core.

However the centralization scores look for structure with a clear centre and periphery. The lower centrality scores based on the intermediary positions (betweenness) and distance (closeness) between investors indicate a lower level of network centrality than found in other sectors. We expect this is a result of a low variation in the centrality scores across different investors. This determines a network structure that is more distributed when we consider the indirect linkages, which matches the lower average geodesic. We can expect to find central biopharma investors with many direct connections. But, the higher average degree and density statistics for biopharma suggest that the network is generally characterised by high connectivity, and therefore a more distributed general structure.

We find the biopharma network is not fragmented, but is distributed across different investors. We have described a network where information will move easily through the network. Biopharma investors have built up many relationships and the presence of several well connected investors reduces the reliance on any particular investor to act as an information source. In terms of control of the network, the distributed structure means an absence of controlling investors. This may suggest the absence of specialist biopharma investors. Compared to other sectors, no minority group of investors coordinates the network.

However, these results are not weighted by the importance of relationships with particular investors, and each relationship is considered equal. To understand how these characteristics may shape the network structure we will use sociograms in later sections. Next we look at the centrality scores of investors, to see how they specialised across sectors.

6.5 *The presence of specialist investors*

An implicit assumption in the discussion above is that investor activity can be separated according to sector activity. We previously noted that dividing activity by sectors may interfere with the overall network structure. We cannot assume that important actors in each sector are not important across all sectors. In this section we attempt to understand the level of sector specialisation of investors.

We use the same measures of centrality as described previously, but report these statistics for individual investors across sectors. We then look for correlations in each investor's centrality scores across each sector, comparing two sectors at a time. We also use two types of correlation measures, listwise and pairwise correlation to generate two different correlation statistics. In the first approach we produce a listwise correlation statistic based on the centrality statistics for each investor, setting the centralities of investors not active in a particular sector to zero. Therefore the listwise correlation analyses all 1585 investors in the data. In the second approach, using pairwise correlation, the correlation statistic analyses only the sector centrality scores reported for each investor, so only analyses a subset of the list of investors. The pairwise correlation analysis, which compares the reported centrality scores of investors across two given sectors, will ignore investors not active both sectors, thus specialist investors are excluded from the pairwise correlation statistic.

By comparing the results of the two correlation statistics, we can highlight the affect of specialist investors, i.e. investors only active in one sector. The pairwise correlation statistic excludes specialists, and by definition only analyses generalist investors, whereas the listwise correlation includes specialists with a zero score for sectors where they are inactive. We illustrate this in the Figure 7.4 over the page.

In Figure 7.3 we show two examples of the differences that can occur in correlation statistics, using eight investors. Investors 1-2 are active in only sector B, investors 7-8 are active in sector A, and investors 3-6, are active in both sectors A and B. We call investors 3-6 generalists and investors 1, 2, 7 and 8, specialists.

Figure 7.3 Examples of centrality correlations scenarios

Example one: Moderately correlated generalist investors						
	High specialisation		Moderate specialisation		Low specialisation	
Centrality scores	Sector A	Sector B	Sector A	Sector B	Sector A	Sector B
Investor 1	0	0.8	0	0.2	0	0.2
Investor 2	0	0.6	0	0.1	0	0.1
Investor 3	0.6	0.4	0.6	0.4	0.6	0.4
Investor 4	0.5	0.2	0.5	0.2	0.5	0.2
Investor 5	0.4	0.3	0.4	0.3	0.4	0.3
Investor 6	0.1	0.1	0.1	0.1	0.1	0.1
Investor 7	0.7	0	0.7	0	0.2	0
Investor 8	0.5	0	0.5	0	0.3	0
Correlation coefficients						
Pair wise	0.84		0.84		0.84	
List wise	-0.66		0.05		0.58	
Example two: Perfectly correlated generalist investors						
	High specialisation		Moderate specialisation		Low specialisation	
Centrality scores	Sector A	Sector B	Sector A	Sector B	Sector A	Sector B
Investor 1	0	0.8	0	0.2	0	0.2
Investor 2	0	0.6	0	0.1	0	0.1
Investor 3	0.8	0.8	0.8	0.8	0.8	0.8
Investor 4	0.7	0.7	0.7	0.7	0.7	0.7
Investor 5	0.5	0.5	0.5	0.5	0.5	0.5
Investor 6	0.6	0.6	0.6	0.6	0.6	0.6
Investor 7	0.7	0	0.7	0	0.2	0
Investor 8	0.5	0	0.5	0	0.3	0
Correlation coefficients						
Pair wise	1.00		1.00		1.00	
List wise	-0.23		0.51		0.88	

In both examples we show the centrality statistics for each investor, in two sectors. We show three scenarios where the specialist investors occupy different network positions: centrally positioned specialists– ‘high specialisation’, moderately central positions – ‘moderately specialisation’, and finally peripheral positions – ‘low specialisation’. In each example we keep the generalist investor centrality scores constant so we can describe how different levels of specialisation in the network result in different correlation statistics. The final point to note, is that we set the centrality scores for investors who are absent from a particular sector to zero (shown in italics). Without this correction the correlations would always report the pairwise correlations, which would only ever include investors 3-6. The listwise correlations are based on all investors 1-8. Changes to the generalist investor correlations influence the result of the list wise correlations. Therefore we must always consider the results of the list wise correlations with respect to the pair wise results.

Our main point is that increasing the centrality of specialised investors consistently reduces the list wise correlations coefficients scores relative to the pair wise results. When we compare statistics for each scenario, the more central (important) the specialised the investors, the larger the difference in pair wise and list wise correlations. This is true even when the generalist investors are perfectly correlated; introducing central specialist investors reduces the overall correlation. The presence of specialist investors who have peripheral positions does not make large difference to the correlation scores.

Our 'list wise' approach means we capture all investors' position in the network. A strong positive correlation coefficient indicates an absence of specialist investors in central network positions. The 'pair wise' approach compares the positions of investors who, due to the fact they operate in at least two sectors, are more general by nature. A high pair wise correlation coefficient indicates that generalist positions in the network structure do not vary according to sector.

Overall we find that irrespective of how we perform the correlations, the centrality scores of investors in each sector are correlated to the centrality scores of the same investors in the total network (all sectors combined). Therefore, investors that are important in individual sectors remain in central positions when the investor's activities are pooled. However our primary interest is in comparing the different sectors.

One issue we have with this method of comparing list wise and pair wise correlations is to understand what constitutes a significant difference between coefficient scores. We decide that rather than compare individual correlation coefficients, we compare the range of correlation coefficients produced for each correlation approach and choice of centrality measure.

In Table 7.4 we find a mixed set of results. The table shows each correlation approach, the centrality measure used and the coefficient range based across the five different sectors (Biopharma, Comms, IT, Healthcare and Other). By using the coefficient range we can talk generally about the position of specialists in the networks, rather than talking specifically about specialists in one sector.

Table 7.4 Summary of correlation results

Correlation approach	Centrality measure	Coefficient range (comparing sectors)
1-List wise	Betweenness	0.42 - 0.83
	Closeness	-0.09 - 0.15
	Degree	0.23 - 0.60
2-Pairwise	Betweenness	0.42 - 0.85
	Closeness	0.12 - 0.47
	Degree	0.45 - 0.75

The presence of specialist sector investors who are central to the networks should result in lower coefficient scores in approach one compared to approach two. For example a biopharma specialist with a high centrality in the biopharma sector, will not be active in other sectors, so we default their centrality score to zero in these other sectors. In the correlation between centrality scores of investors in biopharma versus a different sector, a biopharma specialist will appear as an outlier, thereby reducing the correlation trend. In the case of specialists occupying very central positions, we may find that the listwise correlation is negative. In the second pairwise approach we do not default the scores to zero and specialist investors are excluded. This should improve the second coefficient value by removing the outliers.

In Table 7.4 we find that comparing the range of scores based on betweenness centrality, the range of coefficient values are similar in approach one and approach two. These results suggest that important intermediaries in the network are not tied to specific sectors, but are generally important in all sectors. As we find that the correlation coefficients values based on betweenness are generally moderate to high, we can also say that generalists occupy similar network positions across sectors. Generalist investor's betweenness centralities in the biopharma network are very similar to those in healthcare, IT and the 'Other' sector networks.

However for the degree and closeness centrality correlations, there is some indication that coefficients are lower in the first approach compared to the second. As the minimum and maximum range values are lower in approach one compared to approach two. This indicates that the position of investors in the network in terms of their direct connections (degree) and distance to other investors (closeness) does vary with sector specialists.

For the results of the correlation of investor degree centrality, removing the specialist investors generally gives higher correlation coefficients in approach 2. However, the listwise results are still statistically significant and of a moderate score, indicating that

despite including specialist investors, a positive correlation trend holds in both approaches. It suggests that specialist investors are not central to their respective sector networks.

In general correlations based on investor's closeness centrality scores are weaker than found using the other centrality measures. This indicates that even generalist investor's position in the network, measured by their distance to all other investors, changes according to sector. Comparing closeness centrality scores between correlation approach one and approach two shows a sizeable change in the range of reported coefficient values resulting from the position of specialists in the network. In the list wise approach we find negative associations between investor centralities in different sectors. Here specialist investors appear to influence the results, indicating that their network position relative to other investors is more pronounced. As closeness centrality is sensitive to the core component of a network, it suggests that specialists are a feature of the core network.

When we combine these results, we find that the network importance of specialists comes from having direct contacts (degree) to other investors at the core of the sector networks. However, the intermediary (betweenness) positions are held by generalists. We find these observations agree with the literature. Specialist investors provide an important role in the network through sector specific expertise, which can be utilised by the established investors. Specialists are positioned in the core of the network, but act as an aid to the main industry players, rather than a central player themselves.

6.5.1 Summary

This section has described the general properties of investor networks in the UK, and compared these properties across technology sectors. This research has confirmed that syndication networks are generally well connected and formed from a single component core including the majority of investors. Our results are similar to the network structure described by Kogut et al (2005). In line with a literature on technological uncertainty and information sharing we have found differences in networks across sectors. Biopharma networks were found to be relatively dense with highly connected investors but with a distributed structure.

Finally we find an ambiguous result for examining the importance of investors across sectors. There appear to be two processes at work. We find a core of generalist investors who are central to the structure of all networks regardless of sector. In addition these

investors are supported by specialists who operate in the centre of the network and are well connected, but do not take the prime co-ordinating position.

To confirm these results and explore them further, we need to examine the detailed network structure. In the next section we examine the network representations, particularly focusing on the core network structures. We will include detail on the type of investors and their geographical locations and try to understand what bearing this has on the network structure.

6.6 Mapping of syndication networks

6.6.1 Analysis of the core component

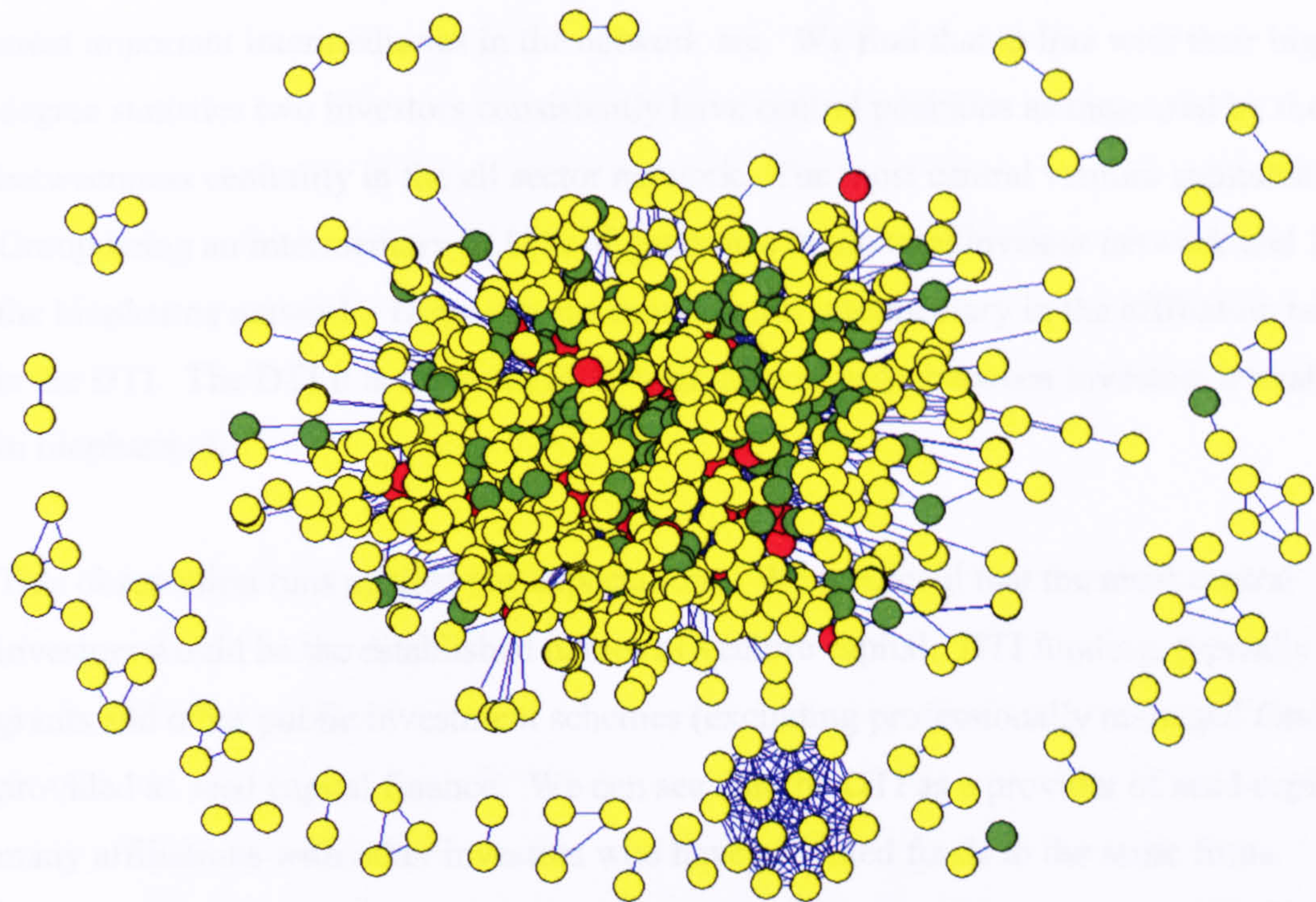
Figure 7.4 shows the network formed from shared affiliations between all investors in the dataset. To this point we have used statistics which include all investors, regardless of their relational activity. However, actors without any relationships to other investors are isolated from the network. To concentrate on the structure of the network we remove investors without any connection to other investors (degree = 0). We also code the vertices by colour to represent the regional coverage of each investor, as calculated from their activity in the total dataset. Investors activity in more than four regions are coded as national, those with interests in more than one region are multi-regional, and investors with interests in only one region are categorised as local.

The network clearly shows a single large dense component at the centre. In line with the expectations from the literature we find that at the centre of the main network component are the national investors having interests across several regions. Conversely as we move from the centre to the periphery we find that we move from investors with a multi-regional presence to those operating solely in one region.

We find that Figure 7.4 is predominantly formed from local investors. Over 70% of investors in the network are local to one region; the largest presence of single region investors is in London and the South East. However this representation does not account for the contribution of investors. If we were to represent the approximate contribution of each investor we would find that the core national group of investors contribute over 40% of the value of investment, based on only a 109 investors²² from the total of 1518.

²² We don't have information on the exact contribution of investors in each deal, so we calculate the amount individual investors contribute by assuming each investor contributes evenly in every investment round, and then sum the total contribution.

Figure 7.4 Sociogram of syndication network of all investors (degree ≥ 1)



Colour code: Investor operating: Yellow = single region; Green = Multi-regional; Red = National (coverage of 4 regions or more)

In the core group of national investors we find established large investors such as 3i Group, Aberdeen Asset Managers, and YFM Group. However, we also find other types of investors, such as companies solely managing VCT (Venture Capital Trust) funds such as Oxford Technology Management, and Government related initiatives including direct DTI finance, as well as investment from charities such as the Wellcome Trust.

We also analyse the network formed from 401 investors active in biopharma firms. For these investors we find increased levels of financial concentration towards the national actors compared to the previous discussion. In the biopharma network, 55% of investment is attributed to just 76 investors. This small group of investors all have a national presence and are located at the centre of the network.

However, we also observe less consistency in terms of the structure of the network according to locational presence. A visual inspection the distribution of locally acting, multi-regional and overseas investors suggests a more even spread. In fact the number of single location investors represents less than 50% of the active biopharma investors. It suggests that investors in biopharma firms need to be larger more established investors. This is in line with the discussion in Chapter 5, as biopharma investment is high risk, only established investors more likely to accept these deals.

We have frequently referred to centrality as an important aspect of network structure. Who are these central investors? We examine the betweenness centrality to understand who the most important intermediaries in the network are. We find that in line with their high degree statistics two investors consistently have central positions as measured by the betweenness centrality in the all sector network. The most central venture capitalist is 3i Group being an intermediary in 18% of geodesics in the total investor network and 15% in the biopharma network. However, the most central intermediary in the affiliation network is the DTI. The DTI it is involved in 19% of the pathways between investors overall (23% in biopharma).

This observation runs against our expectations. We predicted that the most central investors would be the established names of venture capital. DTI funding, typically via grants and other public investment schemes (excluding professionally managed funds), are provided as seed capital finance. We can see that the DTI as a provider of seed capital has many affiliations with other investors who have provided funds to the same firms. However our literature does not indicate what type of intermediary role the DTI plays at a network level beyond providing finance. Clearly as a central investor in the network it has strong potential in terms of the informal circulation of information or participation in VC networking events.

Through common affiliations the DTI is connected to most major investors such as 3i Group, Oxford Technology Management, YFM group. We also find that the DTI has repeated affiliations that link it to other public institutions, such as NESTA, Carbon Trust, Scottish Enterprise and University affiliated bodies such as Cambridge Enterprise. In approximately 25% of cases the DTI money was used as the first recorded investment, rising to over 50% of cases within the first two rounds. However, the range of participation includes the 10th round suggesting that DTI funding is provided across a range of development stages. Finally we note that its central position in the network suggests it fulfils an important role in the financing of firms. However, in terms of the financial significance, or the estimated value contributed by each investor, we find that the DTI is approximately 29 times smaller than 3i, and 11 times smaller in biopharma. This is in agreement with the DTI's report in to Venture Capital provision in England (2005). This report finds that the DTI is one of the main providers of capital in the sub £500k market.

6.6.2 Repeated relationships

We have consistently referred to repeated ties between investors as indicating the strength of affiliation between investors. We find that 92% (93% in biopharma) of the relationships between investors involve a single common investment in a single firm. This type of relationship can be viewed as a relatively weak tie. In Chapter 3 we noted weaker ties can facilitate the distribution of information around a network, and are of significance, particularly for managing uncertainty. The high proportion of weak linkages in UK networks is in agreement with Bygrave (1987, 1988) who suggests the main role of syndication networks is to manage uncertainty.

Our literature review also notes that investors favour trust based ties to organise their relationships, particularly established investors who routinely invest with other similar status investors. Through repeated cooperation and repeated ties these investors build trust. In our network only a small minority of investors are affiliated to more than one firm, and therefore can potentially develop trust based relationships. Of these investors the largest number of repeated affiliations is found between Oxford Technology Management and the DTI. They are linked by 15 common affiliations. Again, this is not expected, this links the UK Government with a Venture Capital trust management firm. In contrast the strongest link between biopharma investors is between two established VC's Avlar Bioventures and Merlin Biosciences, which is what would be expected

To understand the structure and involvement of investors with strong links we can remove the weak relationships between investors to concentrate on investors that have repeated common affiliations. This creates a core of 248 strongly connected investors (from a total of 1586) of which 205 operate in more than one UK region. In the biopharma subset we find a core of 82 investors of which 62 investors have made investments in more than one region. We show these two networks based on strong relationships as Figure 7.5 and Figure 7.6 over the page.

Figure 7.5 Sociogram of affiliation network for all investors where line multiplicity >1

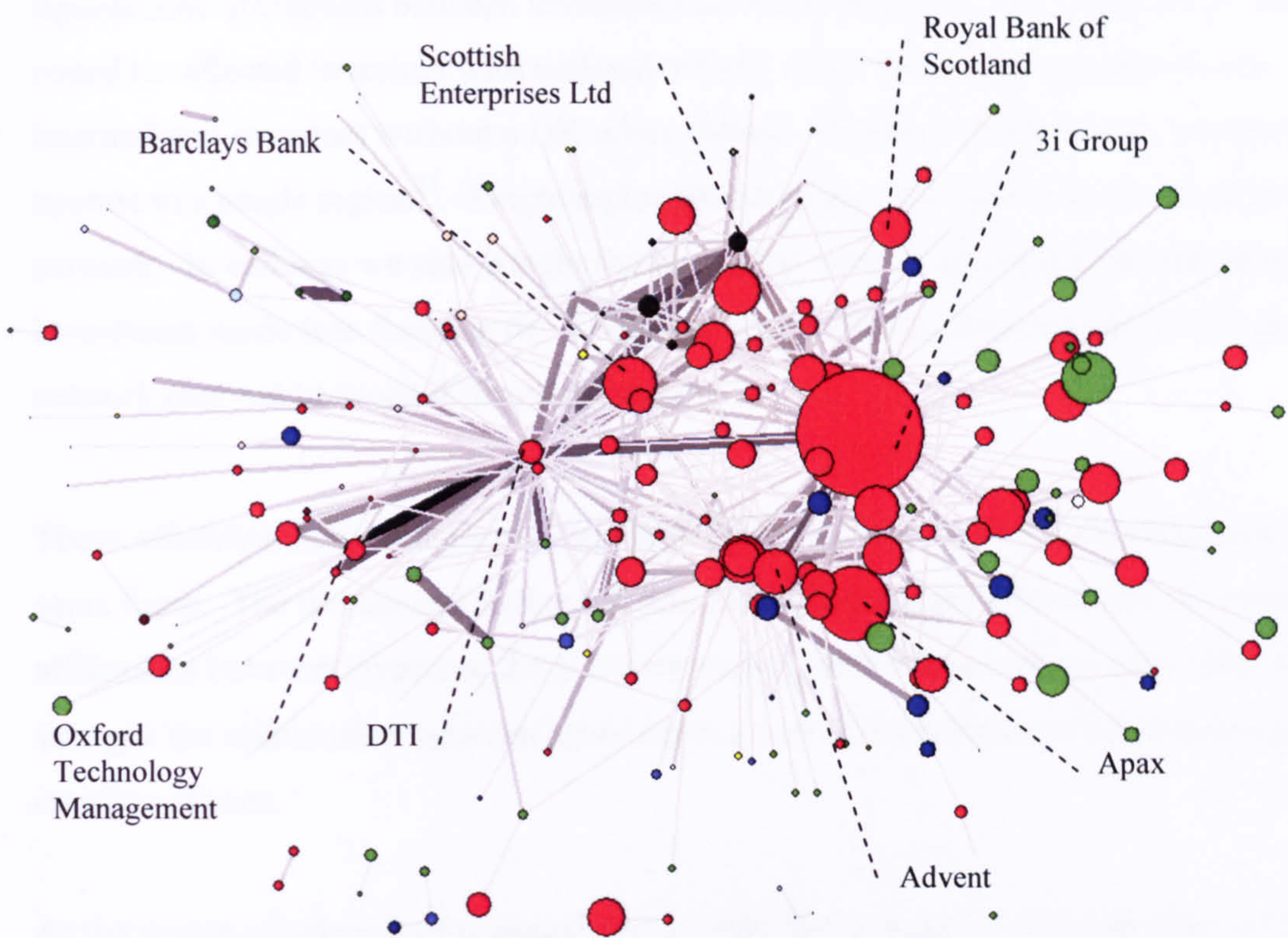


Figure 7.6 Sociogram of affiliation network for biopharma investors where line multiplicity >1

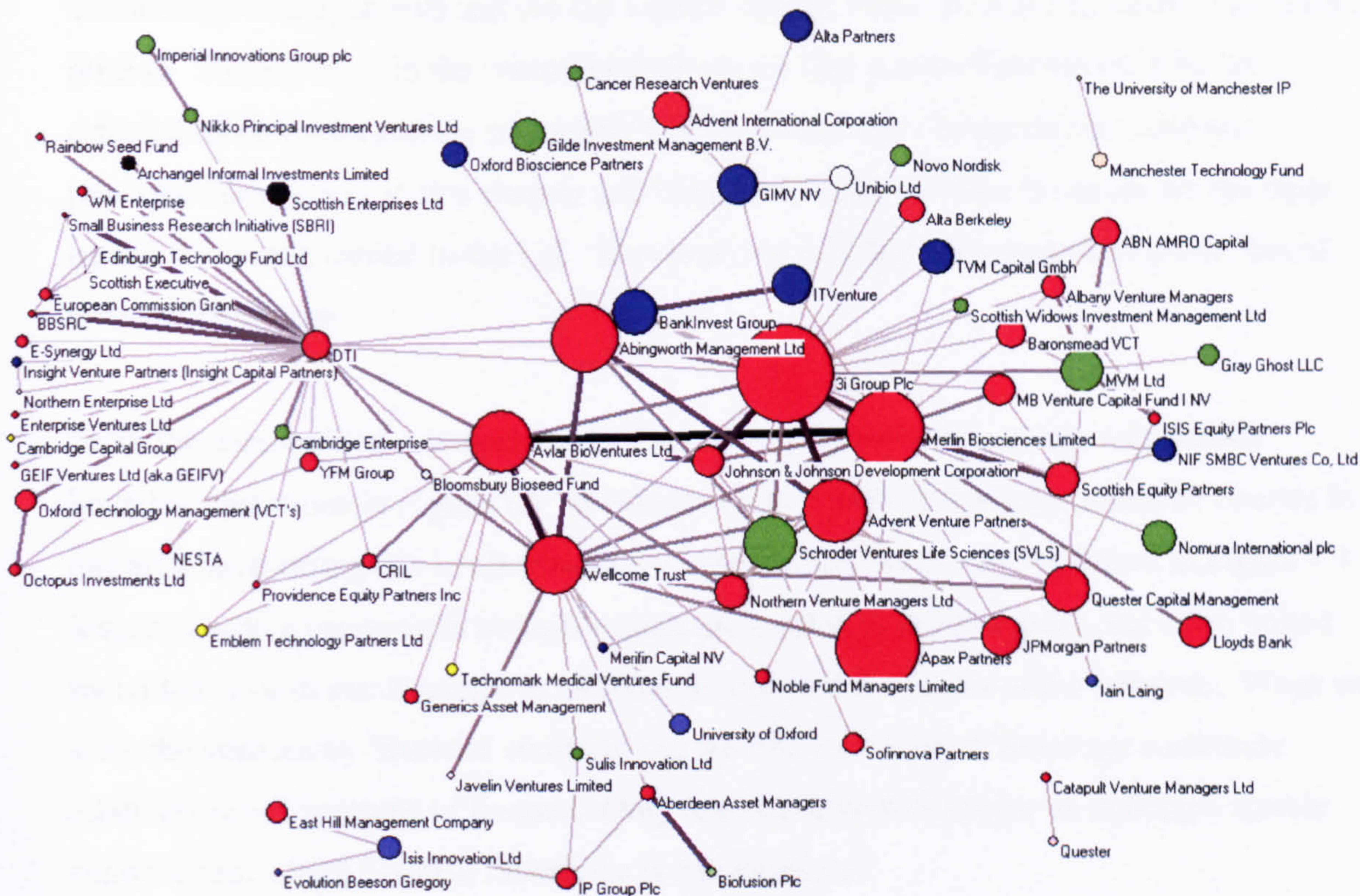


Figure 7.5 shows the total sector network; Figure 7.6 shows the biopharma network. Both figures hide affiliations between investors that occur only once. The vertices are colour coded to reflected investors with national activity (red), multi-regional (green) and international investors without a UK office (blue). We also indicate which investors which operate in a single region²³. Single region investors are most visible in the biopharma network. In addition we also weight the size of the vertices according the estimated investment made (see footnote 6). Therefore vertex sizes are comparable within each network (but not between different networks).

These affiliation networks are created from where investors have provided finance to the same firms. The thicker and darker the line the more common affiliations; the stronger the affiliations between investors, the more we expect them to know about each other and the stronger the relationship between investors in terms of the transfer of information and creation of trust.

At the centre of network of repeated ties we still find a range of different types of investors, ranging from direct public finance (DTI), public-private initiatives (Scottish Enterprise Ltd), International banks (Royal Bank of Scotland), Venture Capital Trusts (Oxford Technology Management) and the top venture capital firms (3i, Advent, Apax, plus several others). Therefore, as in the centrality analysis we find a core of investors, who are established investors and are repeatedly tied to one another. In agreement with our previous discussions, in this chapter and Chapter 3, many of these investors are the main names of venture capital in the UK. However, we still find the presence of public based investment sources.

From the geographical perspective, we find a low presence of investors with locally bounded operations in Figure 7.5. It indicates that relatively few investors who operate in one area have strong ties to other similarly operated investors. As we found in Figure 7.4, investors with a presence in a single region are located in the periphery, but often linked individually or in small groups to national investors at the centre of the network. When we scale the vertices by financial contribution, we find that regional investors contribute relatively small amounts of finance. Only Scottish investors appear as making a sizable contribution, where Scottish Enterprise is one example.

²³ East = yellow; Light blue = South East, White = London, Black = Scotland, Pale Green = Yorkshire and Humber, Mauve = East Midlands, Pale Pink = North West

This only partially matches our expectation for local investors. In line with our expectations, investors with specific single location presence appear connected to the main network with repeated ties to larger investors. However, in contrast to our expectations we find little evidence of strong ties between locally bounded groups of investors. In fact there are few strong links shown between our single location investors. Instead, and not predicated, we observe that investors without a UK base are strongly tied to the network, and to other overseas investors, as indicated by the blue vertices. It is likely that these strong ties help reduce information asymmetries presented from being located away from the deal. The relationship between UK and overseas investors may be similar to the type of boundary spanning relationships found in the US syndication networks.

In the biopharma network we cannot compare the characteristics, such as density, to the overall network, because of the different network size. However, examining the investors in Figure 7.6 shows national investors in biopharma appear as a well connected group with multiple strong relationships between investors. Many of these investors are also present in Figure 7.5, confirming that investors at the centre of the biopharma network are not specialists.

The biopharma network also indicates a potential division where the network is formed of two groupings of national investors. The DTI appears as the central actor in one group, which has relatively weak ties to several investors in the second group. This second group is predominately comprised of large private VC's who have strong connections to each other, including strong ties between 3i, Merlin and the Wellcome Trust. Also noteworthy is the absence of a strong tie between two central investors, Avlar BioVentures and Abingworth Management, both with offices in Cambridge.

In the first group, the DTI is tied to many smaller contributors including the presence of other public-private funds (Scottish Enterprises Ltd, Northern Enterprise runs a RVCF, CRIL was formerly a fund connected to Cambridge University), and University funds (Bloomsbury Bioseed fund is a University Challenge fund, Cambridge Enterprise connected to Cambridge University). The division is less apparent in the unrestricted biopharma network (showing weak affiliations) as investors have a larger number of incidental linkages across the network.

In the biopharma network we also observe that overseas investors (without UK office) are relatively big contributors and closely tied to the central actors. We also find that single

region investors are relatively more active as shown by Unibio investing in London (white), the University of Oxford and ISIS Innovation (light blue) operating in the South East. It is interesting to note that many of the investors associated with Cambridge, such as Avlar Bioventures and Cambridge Enterprise have invested in portfolios that cover regions outside the East and so are coded as having a national or multi-regional presence. As a result the Eastern region (coded yellow) appears underrepresented relative to the finance we have shown it receives in Chapter 6.

6.6.3 Co-investment networks

The previous analysis in this Chapter has considered the network formed from common affiliations to early stage firms. An alternative and more direct form of networking that occurs is through co-investment. If we restrict relationships to only those formed through co-investment in each round, (and so use the investment round as the joining property) do we still observe similar properties?

Overall we find the co-investment and affiliation networks are very similar, the overall importance of investors does not change whether we consider affiliation or co-investment networks. For example the centrality scores of individual investors in each network highly correlated (0.80) indicating that the national players in the affiliation network are central in the co-investment network.

There are three main differences between affiliation and co-investment networks in terms of network structure. Firstly we find that co-investment networks have a smaller core component. In the all sector co-investment network we find the size of the core component is reduced from 1423 to 1038 investors. This result confirms that many investors are weakly linked to the centre of the network through participation in funding the same firm, but not at the same time. A smaller core component size in co-investment networks suggests a smaller network of dedicated VC's who formally work together. Our expectation was that the network would be developed through the addition of two types of investor who operate at periphery of the network; the small locally based investor and the larger corporate investor. In an affiliation type network, these investors would increase the size of the main component, investing in the same deals as other investors indicating that it is likely they create informal relationships with the other investors. However, in the co-investment network we find many of these two types of investor are isolated. For example lone investors are often business angels, regional development agencies, and large blue chip companies (e.g. Vodafone, Microsoft). It indicates that these actors have different

strategies to the core investors which result in them not working directly with other investors, despite contributing resources to the same firms.

Secondly, we find that public finance and seed funds do not feature as strongly in co-investment networks. As with the affiliation network we find that the biopharma co-investment network still shows that the major national investors co-ordinate the network through connections to smaller investors. However, and importantly, we see that from a co-investment perspective many of the seed investors identified such as the DTI, Bloomsbury Bioseed fund and University based funds are no longer central. Instead they located on the periphery of the co-investment network or are absent; because they sometimes invest alone at the earliest stages where private investors may not prepared to provide funds.

Finally, and in contrast to finding a smaller core size, the co-investment network based on repeated ties is larger than found with an affiliation network. We find a core of 391 investors who have opted to syndicate in more than one round in the same firm. As investors repeatedly syndicate together to provide rounds of finance, it indicates that these ties are strong, and represent a core of investors who frequently work with each other. A commitment to finance a firm with a group of investors is therefore binding, and consequences, such as the dilution of an investment, will occur if investors pull out of a syndicate.

6.7 Conclusion

This analysis finds agreement with many of our expectations regarding syndication networks. Analysis of the UK affiliation investor network shows a minority of central actors, with a national presence, forming a dense network core. To operate at the centre of the network investors must be able to invest nationally (potentially internationally), and not be constrained to a particular location. We find that national investors repeatedly work together being affiliated to the same firms, and form the strong relationships between a range of different types of investors, but predominantly private investors form the core network structure. Thus, in contrast to our expectation of regional concentration in networking activity, we find the network organised on a national basis.

Our analysis also indicates that syndicate network structures reflect characteristics of structural social capital discussed in Chapter 3. For instance we find that the networks are organised around key players, demonstrating the importance of investors with high

structural positions. Similarly we find evidence to suggest that strong relationships are formed between these important national level investors, indicating the presence of groups.

The activities of groups of strongly linked investors are not geographically bounded. We find evidence to suggest that the structure of syndication networks in the UK is coordinated at a national level by a central group of investors, in contrast to a simple hub type structure. We suggest this has some similarity to a small world type network structure, although local clusters in the network do not reflect concentrations in geographical investment activity.

However, our expectations regarding differences in networking across sectors are partially upheld. The analysis indicates that sector specialists have prominence in their respective networks, but they are still sub-ordinates to a group of generalist investors. The structures of each sector network showed differences, with biopharma appearing as a densely connected, but relatively distributed network. The sociograms for biopharma also indicated that even with a good general connectivity between investors, the network was formed around two strongly connected structures; one group of the main large private investors and a separate set of smaller public/private investment.

We also compare the affiliation network to a more formal co-investment network. In general the co-investment network suggests weaker relationships between investors in UK SME. We also find the network is more dispersed, as it has a smaller core component. Public investors in the co-investment network are less prominent and lack direct investment links to the established players. Similarly large corporate investors are also shown as peripheral players in the co-investment network.

In contrast, at the core of the co-investment networks the relationships are shown to be very strong formed from repeated investments between the major UK investors. Investors at the centre of the co-investment network have national or international reach and large investment funds. These top investors repeatedly share the financing of the same firms.

It is clear from this analysis that large nationally mobile investors are essential for the provision of finance, particularly in sectors such as biotechnology. We find that these investors predominately co-invest together, but obtain support from a myriad of other smaller investors, indicating that information regarding opportunities spreads relatively well. We find that smaller local investors are present in the networks, but generally

peripheral, contributing to a small number of investments, and often investing alone. Although we expected regional networks to be visible, even in regions such as the East, investors operate on a national basis. We expected to find large national investors acting as ‘spanners’ linking locally tied groups of investors, this was not shown in co-investment network, and only weakly shown by affiliation. Instead we find that strong relationships occur between large national or international investors, who link weakly to a range of smaller investors. It suggests that the large investors have greatest control over opportunities, and although seed investors exist, they lack strong co-investment relationships to major investors, particularly in biopharma.

These observations of syndication have some implications for policy. For example many public funds have been created as a means to seed opportunities for exploitation by large private investors. Oakey (2003a) expects that the deliberate integration of public sources with private investor networks, from the outset, can prevent funding gaps for SME firms and help supply critical follow-on funding for early stages businesses. The lack of integration we observe between these types of investors in biopharma may signal a warning that public funding has attracted further public finance into the same businesses or that public funds have been directed into business which are unattractive to private investors. This is a cautious assessment as many public schemes are only a few years old, and new entrants may naturally be excluded from the main network. We observe a high level of integration in the all sector network, but on a sector basis at the level of repeated relations that we observe the structural weakness in the network, albeit over a relatively short period. One alternative interpretation is that our results may indicate the beginning of the integration of new forms of investors, rather than the continued exclusion of them. Finally we note from a policy perspective that constraining funds to a local region may be a strong disadvantage, as even investors based in Cambridge seek opportunities elsewhere and we find little indication of strong networking between groups of local investors.

An important part of network analysis is to observe what is missing. Our network analysis does not show the involvement of RVCF. In Chapter 4 we noted that these new public-private initiatives were designed to bring public and private investment together in a privately managed fund. Our network analysis confirms our interviews with RVCF managers, that biotechnology investment was considered too demanding in terms of the level of finance and the perceived risk.

In contrast to the Israeli Yozma program, public investment was made into private funds; under the condition that each fund must be partnered with a foreign VC to ensure only credible managers got access to public finance. The Yozma program has been very successful and able to identify promising start ups. There is also evidence that local Israeli Yozma investors have learnt from foreign investors, improving the national VC competences. Many of the original Yozma funds have gone on to raise new private funds (Avnimelech et al, 2004).

We have examined the structure of investor networks at a national level looking for concentrated geographical activity, but have not unpacked the office locations of these national investors. This analysis only provides a partial view of investment activity at the regional level, where stark contrasts in investment activity have been shown. Rosiello and Parris (2008) have found that a high percentage of UK deals involve at least one proximate investor, whilst the bulk of UK investors have an office in London. This may suggest that whilst investment networks are co-ordinated by investors who are nationally active, relationships between investors are partly supported by a physical concentration of investors in London.

We expect that at the regional level different network structures will evolve, in terms of size and density of connections, but more importantly in terms of the type of investors that make up the pool, whether they are nationally or regionally orientated, and located near or afar. We will return to these issues in Chapter 10 in particular focusing on four regional cases, the East, London, Scotland and Yorkshire.

7 Network position and size of syndicates

7.1 Introduction

The syndicate can be regarded as the building block of venture capital networks; in syndicates relationships between investors are formed. In a syndicate a group of investors fund the same firm and take a share in the future financial return. This type of collaboration could be seen as anti-competitive, as investors work together to agree deal terms with the entrepreneurial firm. This makes syndication in venture capital a unique form of investment. According to Lerner (1994) the practice of syndication has long been an activity found in the issuance of equity in the US. The private issuance of equity for venture capital is not strongly scrutinised by the Securities and Exchange Commission and therefore allows investors to co-operate and syndicate when investing in private companies in the US (Lerner, 1994).

The dynamics of syndication have implications for the organisation of venture capital in the UK. We have seen in Chapter 5 and 6 that investment activity is concentrated into specific UK locations. We also show in Chapter 5 that biotechnology investment has a different pattern of concentration from the total investment activity, and less strongly influenced by historical association. However our findings in the previous chapter suggest that networks of investors are organised at the national level, and relationships are concentrated around national actors. However, we do not know whether syndicates, the basic units of the VC network, show evidence of regional concentration or regional variation which reflect investors' preferences to concentrate their investment in particular locations. Therefore this chapter contributes to answering both thesis research questions.

This chapter continues to focus on the thesis theme of exploring the influence of location and technology sector on venture capital activity, but also investigates the extent and nature of relationships between investors. Specifically, we seek to understand whether location and technology sector are important influences on the level of syndication. In order to do this we also consider other factors that may influence syndication activity. For example, we know that the regulatory environment may allow syndication to occur, but why do investors choose to syndicate, who do they choose to syndicate with and what factors drive the size of syndicates?

The chapter is developed as follows. In the first section of this chapter we search the literature for the theory relating to syndication and factors influencing syndicate sizes,

second we provide some descriptive statistics of syndication in the UK relative to the activity in the US, and finally we use the literature to develop a model to explain the level of investor participation in firms. We test this model using statistical regression.

7.2 Motivations for syndication

The literature on syndication has a strong focus on understanding the motivations for syndication. Investors and particularly venture capitalists are generally expected to be motivated by profit. To those unfamiliar with syndication practices, it might seem strange, that given a profit maximising motivation, venture capitalists would be prepared to share investment opportunities. For this reason, understanding motivations to share investments are important to understanding syndication. Therefore, we start with a review of investor motivations, and then review the literature available on syndicate sizes.

We structure this section around the discussion of three categories of motivation for syndication proposed by Manigart et al (2006). These motivations are driven by individual deal considerations, such as investment selection, monitoring and adding value. They are also motivated by considerations regarding the overall management of an investor's portfolio or fund, such as spreading the financial risk through portfolio diversification. Finally syndication can also be related to the specific characteristics of each venture capitalist.

7.2.1 Motivations to syndicate a deal

Lerner (1994) summarises two theoretical perspectives to explain why investors may syndicate. The first, adapted from Sah and Stiglitz (1986), proposes that syndication is used to manage deal selection. Investors are expected to make better investments if the decision to invest is made jointly. The process of agreeing on investments helps to avoid poor quality investments. If several parties are willing to invest, it follows that the opportunity is of higher quality than a deal which attracts only one investor. Syndication will be most useful in early investment rounds where the information asymmetries are greatest. The advantage of syndication is also greatest when experienced investors work together in the initial rounds to evaluate an opportunity jointly. Once an investment is made, other less experienced investors may enter the syndicate in a similar effect to herding (Welch, 1992; Lerner, 1994). Lerner (1994) finds that established investors frequently syndicate in the initial rounds of biotechnology deals.

The second perspective outlined in Lerner (1994) is based on Admati and Ptleiderer (1994). In this case syndication arises in later rounds of investment because the initial investor

needs to maintain a constant share of equity in the business. Maintaining a constant equity share provides the optimum signal regarding the performance of the company. If the initial investor takes significantly more or less equity then information asymmetries between the initial investor and future investors can develop. Information asymmetries between syndicate members may generate concerns that the price of equity is being overstated, as no other party will have had access to the inner workings of the firm to fully assess the deal. The use of syndication is a necessary tool to signal the correct pricing of the firm. Lerner finds that overall the changes in share ownership between rounds is relatively statistic, in approx 70% of investments the change in equity ownership is less than 25%.

Brander, Amit and Antweiler (2002) include an additional justification for syndication based upon the value added to an investment by the VC's experience or contacts. In the value added hypothesis, the investor should prefer to choose investments according to whether they can add value. In this situation syndication is driven by the ability of the group of investors to provide different benefits to the investment. The benefits provided might include recruitment of management or access to networks, markets or future finance. However, Brander et al (2002) and Lockett and Wright (2001) note that syndication for value added incurs costs in terms of management time, collaboration and the organisation of resources. In this case, a decision to syndicate would need to provide benefits significantly greater than the costs of managing and delivering the value added via a syndicate.

7.2.2 Portfolio driven motivations to syndicate

Manigart et al (2006) survey of European VC's finds their primary motivation for syndication is to access other investor's finance. Their findings suggest investors use syndication to increase the number of deals in their portfolio and reduce their exposure to idiosyncratic deal risks. Their survey strongly indicates that portfolio management motivates European VCs to syndicate (Manigart et al, 2006).

Lockett and Wright (2001) also find strong support for the financial risk sharing approach in their survey of a representative sample of UK venture capitalists. They find that the most important reason for syndicating is the size of an investment relative to the size of each investors own fund. The need to syndicate is greatest for deals which are relatively large compared to the size of the fund being managed. In their survey, venture capitalists attach a moderate importance to syndication for obtaining additional non-financial

resources from other investors, indicating that value added motivations are a lower priority than financially driven ones.

In contrast to sharing the financial risk of investing, VCs may need to share information to reduce uncertainty. In similarity to Lerner's (1994) selection hypothesis, Bygrave (1987) suggests that co-investment occurs in high-tech sectors, where uncertainty surrounding deals is greatest. The motivation to syndicate is driven by the need to reduce the uncertainty of investing. However, information sharing operates at the portfolio level, rather than on a deal by deal basis. The choice of syndicate partners may have implications for future investments (as we have described in Chapter 7). For example syndication provides access to information on other deals being considered by the syndicate partners and the opportunity to access information to help investment decisions. Bygrave (1987) finds that uncertainty is reduced by working with specialists investors, showing that hi-tech deals are more likely to involve co-investment than their low tech counterparts. Bygrave (1987) concludes that syndication is more about specialisation and access to expertise and information, than an investors fund size or financial management of the portfolio.

Although Norton and Tenenbaum (1993) suggest that Bygrave's (1997) findings are only partially conclusive they generally support his view. In Norton and Tenenbaum (1993) survey of the portfolio of US based investors, they find that US VCs portfolios were specialised in terms of deal stage or sector. Their findings agree with Bygrave (1987, 1988), that investors need to develop specialist expertise and access to specific types of information on deals and opportunities to help them make investments. Their results, along with Bygrave (1987), suggest that hi-tech sectors demand a greater use of syndicates. However, their findings also indicate that the size of a syndicate may be smaller if specialist investors participate, as specialists understand the sector and may reduce the risks and uncertainty of investing.

A third portfolio driven motivation to syndicate is investor collusion (Lerner, 1994). In this case syndication is used as a method to overstate the performance of an investor's portfolio. Investors join syndicates to gain access to late stage opportunities, as a follow-on investor, particularly when the portfolio company has been successful. By gaining late access to a successful syndicate deal, the follow-on investor can claim greater legitimacy from association to the deal. As it is difficult for outsiders to gain independent information, for example on the length of involvement or exact return of any particular syndicate

member, the follow-on investor benefits from their association to the deal. This helps the follow-on investor market their fund and raise finance.

The original members of the syndicate are likely to accept follow-on investors into profitable deals, as they too can benefit from reciprocation, in the form of access to the portfolios of the new syndicate members. It follows that experienced VCs are most likely to be accepted as follow-on investors, as they offer the best opportunity to return the favour. Lerner (1994) shows that established VCs join investments after a sharp increase in deal valuation. However, smaller sized investors did not benefit from this type of syndication activity.

7.2.3 VC characteristics and motivation to syndicate

A venture capitalists preference to specialise in early stage opportunities can influence their motivation to syndicate. For example, Manigart et al (2006) survey of European investors found early stage VCs were more likely to lead a syndicate and be more specialised than other types of investor. Although managing financial risk was by far the most important motivation to syndicate for any of the surveyed investors, early stage investors were associated with syndicating to obtain value added services, access to deals and deal selection support from other investors. In contrast, later stage investors were very weakly motivated to syndicate by these factors.

An investor's motivation to syndicate can also change with the size of the fund under management. Manigart et al (2006) survey showed that investors with larger funds are less reliant on the financial risk motivation to syndicate, as they can adequately manage the risk in their portfolio. However for smaller investors, syndicating is a means of managing financial risk and overcoming their small fund size. In contrast to Norton and Tenenbaum (1993), small investor specialisation, in terms of preferred investment sectors or locations, was not shown to be strong influence on motivations to syndicate in Manigart et al's (2006) group of European investors. Although, as a high proportion of investors in the sample operated over a restricted geography, it is possible that geographically specialised syndication would arise naturally (Manigart et al, 2006).

Motivations to syndicate can also depend on the roles of each syndicate member in the deal. Wright and Lockett (2002) find that investors in a syndicate do not have equal levels of control. They found that a lead investor will often take a larger equity share to obtain "greater return in recognition of this effort". The lead role may also indicate their greater

responsibility to provide the necessary resources to the investment, rather than syndicating to obtain them. The lead, with the largest share of equity, was found to be more influential in decision making than the authors had expected. The position of lead investor meant decisions could be forced on the syndicate, in stark contrast to the selection hypothesis. Wright and Lockett (2002) observations suggest that the motivation to syndicate is about managing financial risk. On the other hand, investors who frequently syndicate as non-lead or follow-on partners are more likely to place importance on the value adding expertise of other syndicate members (Manigart et al, 2006).

7.2.4 Regional syndication

One element missing from this review of syndication is an appreciation of the factors that drive syndication on a regional level. We have not found literature on this sub-topic for syndication specifically. The literature in Chapter 2 outlines the benefits of investor proximity to deals, such as reducing information asymmetries, maintaining control and monitoring of investments and generally helping to manage the growth of the firm. Investors who operate over longer distances have also been associated with smaller portfolios of deals (Cumming, 2006). Therefore, the tendency of investors to operate locally generates the expectation that areas without local investors may struggle to obtain backing from large syndicates. However, the literature on investor location does not make predictions about the variation in syndicate size according to location.

7.3 Summary

In summary the literature on syndication offers many different explanations for investor's motivations to share access to their investment opportunities. We find that the majority of the motivations revolve around investors need to manage and control their investments as a group or a portfolio of investments. For example investors syndicate to provide access to future opportunities or expert information, manage the perceived performance of their fund or improve the risk profile of their portfolio through diversification. Although it can be argued these motivations may have performance benefits for the firms they invest in, only one motivation for syndication is centred on directly improving the performance of the firm - the value adding motivation. We also find that at the firm level the literature examining the dynamics of venture capital syndicates is less prominent, and makes no prediction about the role of location in determining the size of syndicates. We focus the remainder of this chapter on understanding the factors that influence syndication, and the size of syndicates.

7.4 Modelling syndicate size

In this section we outline a model of factors that influence the size of syndicates in firms. It is based on Guler and McGahan (2006) study of international syndication. As the title of their study suggests, we need to adjust their model to focus on factors important within a nation, such as the UK. Guler and McGahan (2006) suggest several factors influence the size of syndicates. We categorise them into the characteristics of the firm, the characteristics of the investment and the characteristics of the investors. These factors include:

- At the firm level; its sector of operations, national location, founding year and age at first investment.
- At the investment level; the total amount of investment, the number of rounds and how frequently (duration) the rounds occur.
- At the investor level: The nationality of the investor.

We follow a similar model to Guler and McGahan (2006), including the investment level factors listed in their model. However, we note that they include no measure of firm quality, which may be important from a risk based perspective. To account for this we include a measure of firm quality as an additional firm level variable. At the firm level we are interested in syndication occurring within a country, and therefore we model the regional location of firms receiving investment. Therefore we exchange their national measures for those of a regional nature.

We improve the Guler and McGahan (2006) model by including factors to measure a range of investor attributes to control for variation in the characteristics of investors. In Guler and McGahan (2006) the details of the investors for each firm are restricted to only the nationality of the investor. In contrast, Manigart et al (2006) show investor activity and syndication motivations vary according to the type of investor. Bygrave (1987) also indicates that investor specialisation and access to information has a role to play in forming syndicates. Therefore our model includes measures of the characteristics of investors, such as whether each investment involves a sector specialist, and the average portfolio size of investors. We also include the average centrality of investors in the investor network, as investors with many relationships have greater access to information. We also include a measure of the geographical investment preference of investors in the syndicate, including whether the investors are based overseas to indicate the geographical range of investors in each syndicate.

In the next section we discuss each factor expected to influence the number of investors participating in financing a firm, including how each factor is predicted to change the size of a syndicate. We conclude the section by summarising our expectations.

7.4.1 Firm level factors

At the firm level we expect that older firms will have a greater history of activity, be more established, and provide more information for an investor to make an informed decision to invest (Gompers and Lerner, 2000). For this reason we expect that the older the firm at first investment, the lower the uncertainty of investing, and the smaller the resulting syndicate.

The funding environment is responsive to the national business environment (Guler and McGahan, 2006). For example investors respond to wider economic conditions that influence exit windows and other external economic events. We might expect that economic conditions will change investor's tendency to syndicate. Therefore, measuring the founding year of a firm may capture different financial situations and have implications for investors and their syndication strategies. We do not make specific predictions about the direction of this influence, but include this as a control factor.

We have previously discussed regional and sector influences on syndicate size in section 8.2 and 8.3. Guler and McGahan (2006) find that large syndicates are associated with biotech deals and smaller syndicates with consumer related deals. Specific industry risk may play an important role in determining the risk of an investment. Therefore hi-tech sectors such as biotechnology, where information asymmetries are high, are expected to increase syndicate sizes under a financial risk perspective.

The 'value adding' motivation may also result in larger syndicates, particularly in demanding sectors such as biopharmaceuticals where a variety of investor backgrounds can contribute different types of value to the firm. Direct benefits for the firm include recruitment assistance or strategic and business guidance, whilst indirect benefits can include benefits predicted from social capital theory which might arise from investor prestige or access to resources and contacts etc. However, we have noted in the literature review that the co-ordination of investors to provide resources is costly and in biopharmaceuticals these costs will be ongoing through the lengthy development times. Under the value added hypothesis we would expect an optimum number of investors to evolve as acceptable in the industry which would minimise the size of syndicates. Under

these assumptions we might expect syndicate size to be relatively constant across sectors. In a survey of European investors Manigart et al (2006) found weak support for value adding motivations to syndicate, although this support was stronger for early stage investors.

Our expectations regarding the influence regions on syndication are less clear. We have consistently found regions to provide different venture capital environments. It suggests different regions may offer more supportive systems. Following a value adding motivation, a syndicate of investors with different experiences can better support a firm, resulting in larger syndicates in particularly well supported regions. From a purely financial perspective there is no reason to assume that geography prevents the flow of finance, therefore from a financial risk perspective regional variations are not important, so syndicate should not vary with geography once we control for the other factors.

Guler and McGahan (2006) note that smaller syndicates, or single investor deals can arise when the risk is low relative to the return. Small syndicates can also occur when the deal quality is perceived as high, such that the ratio of risk to reward is balanced in favour of maximising the reward, rather than syndicating to reduce risk. In such cases larger financial risks may be taken. Therefore, a higher deal quality may reduce syndicate size, as investors try and capture the full potential return.

7.4.2 Investment level factors

Sahlman (1990) suggests that the staged infusion of capital can be used to control investments, and reduce the risk of making bad decisions. However, this must be balanced against the costs of staging an investment. The costs of staging a deal maybe large as the deal must be re-assessed and changes in the investor syndicate may occur (Guler and McGahan, 2006). It is unclear whether deals with more rounds will involve a greater number of investors. However, a staged deal provides the opportunity to stop an investment if it performs badly (ibid). Given the more cautious nature of UK investors, investments with many rounds are likely to indicate successful investments, and so more likely to attract new investors.

It also follows that if an investment is staged, a period of time elapses between each investment. The duration between investment rounds may also play a role in managing the risk of investing. Guler and McGahan (2006) note that Gompers (1995) found investment uncertainty was linked with shorter durations between rounds, in order to closely monitor

the firm's progress. However, Guler and McGahan (2006) find duration between rounds to be unimportant after controlling for the other factors; therefore we will exclude it.

Guler and McGahan (2006) include total investment in the firm, as a factor likely to increase syndicate size. The emphasis on syndication as a tool to manage financial risk means we should expect syndicate sizes to reflect the inherent risk of each deal. Risk per investor reduces with the size of a syndicate. In line with this Brander et al (2002) suggest that syndicated investments may be more risky than those involving a single investor. This indicates that deals requiring large levels of financial support should require larger syndicates.

However, our discussions have also indicated that there are costs to adding additional investors. The costs of larger syndicates come from managing an investment involving a large number of stakeholders. These types of costs may restrict the number of investors to a natural maximum. In the model we will include the square of total investment to test for an inverted "U" type parabolic relationship.

7.4.3 Investor level

We augment the Guler and McGahan (2006) model with the use of more information on investor specific factors which may influence syndicate sizes. We expect that investors who specialise in a particular sector will reduce the syndicate size. Specialist investors can add greater value to their investments, reducing the need to syndicate for expertise, particularly in the initial investment rounds. Similarly their specific sector knowledge should reduce their perception of uncertainty compared to more generalist investors. This is expected to reduce their need to share the risk with other investors.

We also include two other measures of investor characteristics; the average centrality of investors in the syndicate and the geographical coverage of investors. From the literature we review in Chapter 7, we can expect that investors with a central network position are the established names of venture capital. It follows that established names are the most experienced investors and have developed capabilities in investing. The presence of central investors in a syndicate should reduce the need for additional investors.

As we identified in the literature review, there is less known about the influence of the geographical coverage of investors in a syndicate on syndicate size. Therefore we include this measure to understand the role of investor's geographical presence on syndication. To

reflect the different types of investor, we examine each investor's geographical portfolio coverage, in terms of whether they operate in a single region, nationally or are based overseas. Guler and McGahan (2006) found that the presence of US investors in non-US deals increased syndicate size, indicating that overseas investors may be connected to larger syndicates. As overseas investors are expected to be relatively remote from the investment, this would suggest a financial motivation for syndicating.

We would expect investors who operate locally to benefit from being embedded in the local area, having greater opportunity to assess the risks of investing and therefore be able to minimise investment uncertainty. We expect that, after controlling for other factors, local investors should be able to take greater risks compared to more distant investors, reducing the need for large syndicate sizes. In contrast, investors with a more national outlook are likely to invest over greater distances and more likely to reduce the financial risk of investing by syndicating. Therefore we might expect, that after controlling for other factors, that national investors are associated with larger syndicates.

We also control for the size each syndicate member's portfolio. Manigart et al (2006) suggest that larger investors are less financially motivated to syndicate. We would expect that the greater the value of the portfolio of each syndicate members, the smaller the overall syndicate size.

Finally the initial investment rounds may have important implications for setting the structure of the syndicate. For example Lerner (1994) shows established investors operate in initial rounds syndicating to select only the best deals. It logically follows that the overall size of the syndicate may be influenced most strongly by the investors in the initial rounds. We allow for this possibility in the model by controlling for the investor characteristics at the first round. In particular we consider the presence of specialist investors, the average size of the syndicate member's portfolio and network centrality scores at the first round of investment in each firm.

7.4.4 Empirical conjectures

Our discussion in the previous section has generated expectations regarding the influence of specific factors on the number of investors required to support an investment in a firm (*no of investors*). Next we generate a model which can be used to test our expectations. In the model we include the following independent factors expected to influence the number of investors in a firm; dummy variables for the regional location and technology sector,

age at first investment (*Age at first invest*), year of firm founding (*Founding*). At the investment level the model includes, total investment (*Total invest*), the number of investment rounds (*Rounds*), the square of total investment (*Investsq*), and the quality of the deal (*Quality*). To control for the specific characteristics of investors in each syndicate the model includes, the average centralities of all investors in the syndicate (*Central*), the average centrality of investors in the first round (*Central_R1*), the presence of overseas investors (*Overseas*), the proportion of national investors (*P_National*), the proportion of local investors (*P_Local*), the presence of specialist investors (*Specialist*), the presence of specialist in the first round (*Specialist_R1*), and finally the average size of the portfolio of first round investors (*Ave portfolio_R1*).

Table 8.1 summarises the predicted direction of influence on the number of investors per firm. These predictions are expected to be approximately linear in terms of the independent variables relationship to the dependent variable, with the exception of the *Investsq* variable.

Table 8.1 Predicted direction of influence of variables on syndicate size

Variable	Predicated influence on dependent variable	Motivated by:
Regional dummies	No significant impact	Financial risk
Sector dummies	Biopharma connected to more investors than other sectors	Financial risk
Age at first invest	Older firms have smaller syndicates	Financial risk
Founding		
Total invest	Larger investment related to more investors	Financial risk
Rounds	More rounds the greater opportunity for investors to access deal – larger numbers of investors	-
Investsq	Positive non linear effect	Value added
Quality	Higher quality reduces the number of investors	Financial risk
Central	More central investors reduce number of investors	Deal selection
Central_R1	More central investors in the first investment round reduce number of investors	Deal selection
Overseas	Larger syndicates connected to presence of overseas investors	Financial risk
P_National	A greater proportion of national investors should increase syndicate size	Financial risk
P_Local	A greater proportion of local investors should reduce the need for additional investors	Value added
Specialist	Specialist knowledge reduces number of investors	Value added
Specialist_R1		
Ave. portfolio_R1	Larger portfolio reduces number of investors	Financial risk

The *Investsq* variable is used to capture any non-linear effects of investment size with respect to the number of investors. In the case of a significant positive coefficient on *Total invest*, β_{inv} , and a significant negative coefficient on *Investsq*, β_{invsqr} , then according to

Wooldridge (2003 p.683) we can conclude that syndicate size increases with investment to a maximum value, at which point the total investment equals:

$$\beta_{inv}/(-2\beta_{invsqr}).$$

In the UK the emphasis in the literature on syndication is towards risk management. This emphasis suggests that syndication is motivated by the management of finance, rather than a shared responsibility to add value, or access to specific experience. Therefore our expectations favour this hypothesis, as indicated by the motivation column.

7.4.5 Method

We use econometric analysis, using the software STATA to test whether the factors we propose are able to explain the variation in syndicate size of early stage investment. As the dependent variable is the count of the number of investors who provide finance to a particular firm, we need to use a count data estimation technique. The standard ordinary least squares (OLS) estimator is not applicable to count data models, as the dependent variable is limited to a few values and is non-negative. In the standard OLS estimations a situation can arise where the predicted value of the dependent variable based on the independent variable coefficients are less than 0. However applying an exponential form to our model prevents this problem (Wooldridge, 2002).

We apply two commonly used count data estimation methods, known as the Poisson and the Negative Binomial estimation, the general form is shown below. In both estimation techniques the conditional mean, or number of investors in firm i , is given by the exponential of the product of the i th row of X and β . X is a data matrix of dimensions, $i \times k$ (where k is the number of variables in the model) and β is the vector of coefficients for each variable (Long, 1997):

$$No.of\ investors_i = Exp(X_i\beta)$$

A final point regarding the estimation method is that our dependent variable cannot equal zero, as we observe no zero sized syndicates. This means the dependent variable is truncated. Both the Poisson and Negative Binomial distributions need to be adjusted to account for the truncated distribution of the dependent variable. We use the truncated regression option in STATA to correct for missing zero values.

As with the previous estimation methods in Chapter 5 and 6, estimating the model produces estimates of the β coefficients. The value of the coefficients indicates that for a

unit change in the k^{th} independent variable (x_k), holding other variables constant, the expected dependent variable count changes by a factor of $\text{Exp}(\beta_k)$, where β_k is the coefficient value for x_k . Alternatively, coefficients can be interpreted as having a percentage influence on the dependent variable of, $100(\text{Exp}(\beta)-1)$ (Long, 1997 pp.224-225).

7.4.5.1 Issues in estimation

Poisson and its adjusted form, the Negative Binomial, both use the exponential form. In the Poisson model the probability of a particular count (number of investors) is determined by a Poisson distribution. In the Poisson distribution, the mean is a function of the independent variables (Long, 1997). However, the Poisson model implies a restriction that “the mean and the variance of the number of occurrences to be equal” (Kennedy, 2003). This restriction is often invalid as the variance is often greater than the mean and is known as over-dispersion. To allow for over-dispersion, the Poisson model can be adjusted to a Negative Binomial model. This is achieved by adding a random error term ε_i , transforming $X_i\beta$ to $X_i\beta+\varepsilon_i$. Thus it is assumed that the expected value of $E[\text{Exp}(\varepsilon_i)]=1$. This transformation does not affect the expectation of the dependent variable, but makes it possible for the variance conditional on the independent variables to be different from the conditional mean (Long, 1997).

We test for the presence of over-dispersion using the alpha values (the ratio of variance to mean) reported by STATA. We consistently find the presence of over-dispersion in our Poisson estimations, as shown by an alpha value statistically different from one. As over-dispersion in Poisson estimation can lead to bias in the standard errors this can influence the statistical testing (z-tests) of the significance of the independent variable coefficients. To avoid this problem we concentrate our analysis on the Negative Binomial regressions. For completeness, we also show a table including the Poisson results in the chapter’s appendix, as the coefficient values are consistent even in the presence of over-dispersion.

Our model includes independent factors that are qualitative. For example our model includes factors such as the region in which a firm is based, or the presence of a specialist investor. In cases where the variable reflects the presence of absence of a certain characteristic, such as the presence of specialist investor, then the use of dummy variables is simple. To include this type of data in the model we use dummy variables which can take binary values (either 0 or 1). We also use several binary dummy variables to describe factors such as location or sector; in these cases a dummy variable is required for each category (e.g. each region).

When several dummy variables are used to describe an aggregate property of the data, such as a relationship to localities (i.e. regions), they can cause a downward bias in the standard errors of the estimated coefficients the independent variables. The bias is a result of correlation which can occur between the errors terms associated with each group of individual dummy variables describing the aggregate characteristic (e.g. the regional or sector), as unobserved correlations may exist between the dummy variables (Moulton, 1990; Kennedy, 2003). This can cause variables to appear overly significant. We use robust standard errors in the calculation of the statistical significance of variables to correct for this problem. The use of standard errors also corrects for heteroskedasticity in the estimation and generally reduces the level of spurious reporting in significance testing.

Another issue with the aggregate dummy variables is multicollinearity, which occurs when a directly relationship exists between the independent variables because of the way they have been coded. For example if each firm is assigned to a sector, and a dummy variable included for each sector, then a perfect linear relationship is created by the set of dummy variables. For each firm it is possible to determine its sector without the full set of dummy variables. A relationship between independent variables creates problems in determining the correct coefficient values, as they are inter-related. To avoid multicollinearity we drop a dummy variable from each of the regional and sector categories. The coefficient values on the remaining dummies should be interpreted with respect to the omitted variable, i.e. the dropped variable becomes the reference variable (Kennedy, 2003).

However, we also find additional multicollinearity in our estimation as a result of independent variables having a similar over overlapping influence on the size of syndicates. This also prevents the STATA from producing reliable estimates. For example we find founding year and age at first investment create a source of multicollinearity. Both variables are highly correlated and the multicollinearity arises as a property of the dataset, as in later years firms receive their first investment round at a younger age. We can drop founding year from the model without loss of the explanatory power, which solves the multicollinearity problem. Similarly, we cannot include investor centrality and the average size of the portfolio in the same estimation model because of multicollinearity. We find that both factors have a very similar influence on the dependent variable suggesting they measure the same property. Finally we also find that our measures of 1st round activity, in terms of investor specialisation, centrality and average portfolio size also have a very similar influence to their counterparts which measures all round activity. This supports the view that the first investment round captures important information on the

total predicted syndicate size. We generally include the 1st round measure in our model, with the exception of centrality where we include the more inclusive measure.

7.4.5.2 Estimation process

We report the Poisson and Negative Binomial estimation results for six different models. We summarise our estimation strategy in Table 8.2. In regression models 1-3 we build the analysis to include firm and investment level variables. In models 4a-4c we include different variants of the independent variables to minimise multicollinearity issues, and confirm the consistency of results. In models 5 and 6 we include the measure *P_national* to see how this affects the other investor level variables which were included in model 4a and 4c.

Table 8.2 Estimation strategy

Model	Regression description	Reference model in sensitivity analysis
1	Results regressing only the firm level variables	n/a
2	Results regressing only the investment level variables	n/a
3	Models 1 and 2 combined	2
4a	Extend model 3 by including investor level variables (<i>Centrality and Specialist</i>)	3
4b	Alteration to model 4a exchanging <i>Centrality</i> for the <i>Ave. portfolio R1</i>	3
4c	Alteration to model 4a exchanging <i>Specialist</i> for the <i>Specialist R1</i>	3
5	Extend model 4a by including <i>P_national</i>	4a
6	Extend model 4c by including <i>P_national</i>	4c

We also test for the sensitivity of including particular groups of variables in the model. We group our variables according to firm level, investment level and investor level characteristics. A Likelihood ratio and Wald test are used to indicate whether we can restrict the coefficients of all variables within a particular group to zero. If the restriction is accepted, it shows that the group of factors have low explanatory power. We consistently find both sensitivity tests reject the zero restrictions for each group of factors. Thus, each group of factors contributes to explaining the variance of syndicate size. We report the results of these tests with the estimations in section 8.5.

7.4.6 Data

To operationalise the factors described in section 8.4.4, we collect data shown in Table 8.3 from our Library House database at the firm level. A description of the Library House dataset is given in Chapter 4. In contrast to previous chapters which use aggregated regional statistics, this chapter benefits from using the firm level data. The Library House data is used to produce a cross section of data based on 1562 firms. However, due to

missing values, particularly relating to the total investment, the minimum number of observations used in the estimation is 1004. To reduce the use of regional dummy variables we group regions together, so that for example the North East and North West are grouped as the North²⁴. We note that only variables in bold are included the model, whilst all variables in the table are shown in the correlation table for completeness.

Table 8.3 Data used to measure factors influencing syndicate size

Series name	Description	Variable
no of investors	Count of number of different investors in a firm	Dependent
Firm variables		
london	Equals 1 if firm based in London, otherwise equals 0	Dummy
east	Equals 1 if firm based in East, otherwise equals 0	Dummy
scotland	Equals 1 if firm based in Scotland, otherwise equals 0	Dummy
North	Equals 1 if firm based in Northern England, otherwise equals 0	Dummy
Midlands	Equals 1 if firm based in the Midlands, otherwise equals 0	Dummy
South	Equals 1 if firm based in Southern England, otherwise equals 0	Dummy
Wales&NI	Equals 1 if firm based in Wales or N.Ireland, otherwise equals 0	Dummy
It	Firm activity in Information Technology	Dummy
Comms	Firm activity in Communications	Dummy
HC_red	Firm activity in Healthcare (excluding biopharmaceuticals)	Dummy
Biopharma	Firm activity in biopharmaceuticals	Dummy
Other_red	Firm activity in Other sector (financial/media)	Dummy
Age at first invest	Age of firm in years at first investment	Independent
Founding	Year firm founded	Independent
Investment variables		
Total invest	Total investment in each firm in £m	Independent
Rounds	Number of rounds of investment in each firm	Independent
Investsq	Square of Total Investment variable	Independent
Quality	Firm has IPO or exit recorded in database.	Dummy
Investor variables		
Centrality	Average centrality ²⁵ of all investors in firm	Independent
Overseas	Syndicate includes overseas investor	Dummy
Specialist	Syndicate include specialist investor (only invests in one sector)	Dummy
Specialist_R1	1 st round include specialist investor (only invests in one sector)	Dummy
Ave portfolio_R1	Average value of the investment portfolio of 1 st round syndicate investors (Each investors portfolio is calculated from their total commitment to all firms in the database)	Independent
P_Local	Portion of investors in firm coded as local (investment in only one region)	Independent
P_National	Portion of investors in firm coded as national (investments in 4 regions or more)	Independent

7.4.6.1 Descriptive statistics

In Table 8.4 we summarise the descriptive statistics of the data. The average firm in this dataset has 2.5 investors, was founded in 1999, and received a total of 2 rounds of a total value of £6.7m. We note that the standard deviation of investment is large relative to the mean, indicating that a wide range of investment levels are captured in the data. Similarly,

²⁴ Reducing the number of dummy variables within a particular class aids interpretation of the variables in later analysis.

²⁵ Centrality based on intermediary positions in the network – other centrality measures provide similar results.

we also see a large variation in founding year, given that one standard deviation about the mean gives a range of 1993-2005, although the minimum value for founding year indicates the presence of outliers firms.

Table 8.4 Descriptive statistics of data used in chapter

Variable	Obs	Mean	Std.Dev	Min	Max
no of investors	1562	2.50	2.10	1.00	17.00
London	1562	0.24	0.43	0.00	1.00
East	1562	0.12	0.33	0.00	1.00
North	1562	0.15	0.36	0.00	1.00
Midlands	1562	0.10	0.30	0.00	1.00
South	1562	0.24	0.43	0.00	1.00
Wales&NI	1562	0.05	0.22	0.00	1.00
Scotland	1562	0.09	0.29	0.00	1.00
IT	1562	0.33	0.47	0.00	1.00
Comms	1562	0.10	0.30	0.00	1.00
HC	1562	0.08	0.27	0.00	1.00
Biopharma	1562	0.11	0.32	0.00	1.00
Other	1562	0.38	0.48	0.00	1.00
Age at first invest	1562	1.67	3.84	0.00	43.00
Founding	1562	1999	6.07	1903	2006
Total invest	1013	6.71	17.32	0.01	304.15
Rounds	1562	2.01	1.32	1.00	11.00
Investsq	1013	344.89	3238.44	0.00	92507.22
Quality	1562	0.05	0.21	0.00	1.00
Centrality	1557	0.01	0.03	0.00	0.14
Overseas	1562	0.05	0.21	0.00	1.00
Specialist	1562	0.07	0.26	0.00	1.00
Specialist_R1	1562	0.05	0.21	0.00	1.00
Ave. portfolio_R1	1530	74.93	193.43	0.00	889.97
P_Local	1562	0.32	0.38	0.00	1.00
P_National	1562	0.52	0.41	0.00	1.00

In the appendix we report the pair wise correlation coefficients between the variables. As we have previously discussed issues presented by multicollinearity in section 8.4.5, we use the correlation analysis to understand the association between the independent and dependent variables.

We find the correlation analysis indicates good support for the choice of variables in the model. The majority our independent variables are correlated with the number of investors at the 5% significance level (as indicated by *). The main exceptions are individual dummy variables relating to a specific region or sector, which also show variation according to the direction of association. This suggests heterogeneity across regions or sectors with respect to their association with firm syndicate size. We also find that the variable *Quality* is not shown to be associated with syndicate size.

The directions of association are also in broad agreement with our expectations. An exception is *P_Local* and *P_National* which have associations to syndicate size in the opposite direction to that predicted. It is possible that these variables reflect more than just geographical characteristics of investors. For example geographical coverage may be correlated with investor size or experience. Therefore we interpret these variables carefully in the estimation.

In contrast to our expectations regarding the importance of the early involvement of specialist investors, we find that correlation of *Specialist* with *no of investors* is stronger than for *Specialist_R1*. As we include both variants of the measure of specialist in the estimation we can evaluate their influence on syndicate size more fully when controlling for other factors. In the next section we discuss our syndicate data in more detail in view of other studies in the UK.

7.4.7 Prevalence of syndication in the UK

Syndication amongst VCs varies according to national location and sector. In the US Sorenson and Stuart (2001) find syndicates in two-thirds of all US VC backed firms in the period 1986-1998, with a typical firm receiving investment from on average 5.3 VCs. Manigart et al (2006) shows that European investors on average indicated an expectation to syndicate between 20-40% of investments, with a similar percentage of investors intending to participate as lead within the deals they syndicate. In Canada, Brander et al (2002) find that 40% of investment deals are syndicated. In the UK, Wright and Lockett's (2003) analysis based on EVCA survey data finds that 27% of deals were syndicated in 1999, falling to 13% in 2000. Thus, they argue that the proportion of deals syndicated in the UK is behind Europe (29.5%) and the US (63.6%).

Using the Library House dataset we find that 77% of firms receive finance from more than one investor, however if we consider only institutional investment (involving formal VC organisations) this falls to 65% of deals. This difference can be explained by the fact that other forms of finance available from business angels, charities etc, are generally focused on providing high risk early stage investment, and therefore syndication is used more widely. In the statistics for the institutional deals, these informal investment deals are excluded.

For individual rounds of investment the level syndication is much lower; typically 35% of rounds involve more than one investor, rising to 46% of institutional deals. These

proportions are consistent with Wright and Lockett (2003) analysis of EVCA data. However, although we observe a lower level of financing activity in the year 2000, we do not observe a fall in syndication activity. Therefore, in our data, the impact of the internet bubble did not influence syndication in early stage investment. One explanation for the difference in syndicate statistics is that the EVCA data includes the full activity of all members, rather than just early stage investment.

We also find sectoral differences in the extent of syndication. In total 88% of all biopharmaceutical firms in our data are funded by more than one investor, and 86% of these receive institutional finance. This level of syndication is higher than found in other sectors. For individual investment rounds, the level of syndication is also higher than average. For example 41% of all biopharmaceutical investment rounds are syndicated, rising to 54% of institutional biopharmaceutical rounds.

Thus, syndication is a feature of UK investment activity, especially when we concentrate on the biopharmaceutical activity. However, we find that proportion of firms receiving investment from more than one investor, is much higher than the proportion of rounds involving co-investment. This result indicates that the structure of syndicates change with the growth of the firm. To capture the full participation of investors in each firm we follow Brander et al (2002) and analyse our data using two measures of syndication activity. The usual understanding of syndication is at the level of individual rounds. We also include a measure for the full participation of investors in firms overall to represent the wider demand for investors in biotechnology and pharmaceutical deals. A measure of syndication by round may underestimate the wider participation of active regional investors, such as seed funds, that may only participate in the initial rounds. In both statistics, a high value indicates greater investor cooperation and involvement for deals in the region

We also compare the syndication statistics for each GOR and across different investment sectors, including Communications (*Comms*), Information Technology (*IT*), Healthcare excluding Biotechnology and Pharmaceuticals (*Healthcare*), Financial services, media, consumer based services (*Other*), Biopharmaceuticals (*Biopharma*) and All (*All deal*).

Table 8.5 shows the syndication statistics per round. On average each round of investment involved 1.7 investors, although *Biopharma* has the highest number of investors per round on average (2.1); deals classified as ‘Other’ (1.5) has the lowest syndicate size. However,

within sectors there is also variation across regions; for example, *Biopharma* deals on average involve 2.3 investors in the South East and Eastern regions, but only 1.2 investors in the North East and the West Midlands.

Table 8.5 Syndication of investors per round

GOR	Comms	IT	Healthcare	Other	Biopharma	All
East	2.2	1.7	1.6	1.7	2.3	1.9
East Midlands	1.0	1.3	1.7	1.5	1.8	1.5
London	1.8	1.7	1.4	1.4	2.1	1.6
North East	1.2	1.5	1.3	1.4	1.2	1.3
North West	1.7	1.5	1.4	1.4	1.5	1.5
Northern Ireland	1.7	1.8	1.5	1.6	1.8	1.7
Scotland	1.6	1.9	2.2	1.7	2.2	1.9
South East	1.8	1.7	1.5	1.5	2.3	1.8
South West	1.5	1.9	1.7	1.5	1.9	1.7
Wales	1.2	1.0	1.1	1.6	1.6	1.4
West Midlands	1.5	1.7	1.3	1.4	1.2	1.5
Yorkshire	1.7	1.4	1.8	1.2	1.5	1.4
Grand Total	1.8	1.7	1.6	1.5	2.1	1.7
Rounds	889	1693	340	1576	666	4773
Paired T-test	*	*	**	**		**

Paired T-test comparing each sector to Biopharma syndicate data. Rejecting null hypothesis of no difference at 10% *, 5% **, 1% *** confidence levels²⁶

We find that the number of investors per round increases to a peak at the 4th round of 2.0 investors in *All deal* and 2.6 in *Biopharma*. This indicates that as firms grow the syndicates become larger. This is consistent with Lerner (1994) who finds the number of investors per round in US biotechnology firms increases from 2.7 in round one to 5.3 in 3 or more rounds. In our data, beyond the fourth round of investment the syndicate size reduces, perhaps as smaller investors struggle to maintain their equity position

In Table 8.6 we show the syndication statistics in terms of the number of investors involved in each recorded firm. These syndication figures are higher on average than in Table 8.5, by just under one investor (2.6 compared to 1.7). This result suggests that the composition of investors changes throughout the growth of the firm.

In Table 8.6 we also find a large difference in the overall syndicate size for *Biopharma* having on average 3.5 investors compared to 2.1 on average per deal. We also find variation across regions from 2.2 to 3.3 investors in *All deal* and a larger range of 2.3 to 4.1 investors per firm for *Biopharma*.

²⁶ Paired T-test indicate significant differences between syndication levels for Biopharma versus other sectors.

Table 8.6 Syndication of investors per firm

GOR	Comms	IT	Healthcare	Other	Biopharma	All
East	3.3	3.0	2.8	2.6	4.0	3.1
East Midlands	2.0	2.0	2.3	2.2	2.4	2.2
London	2.7	2.7	2.7	2.2	3.0	2.5
North East	2.6	2.3	1.7	2.5	3.3	2.5
North West	2.0	2.2	2.3	2.0	2.9	2.2
Northern Ireland	2.0	2.8	2.4	2.3	2.3	2.5
Scotland	3.0	3.3	3.5	2.9	4.6	3.2
South East	2.9	2.8	2.9	2.4	3.6	2.8
South West	2.3	2.6	1.5	2.1	3.7	2.5
Wales	6.0	1.7	1.8	2.7	3.0	2.6
West Midlands	2.7	2.5	2.0	1.9	2.3	2.1
Yorkshire	2.6	2.2	2.6	1.9	3.0	2.3
Grand Total	2.8	2.7	2.6	2.3	3.5	2.6
Firms	189	658	137	731	215	1930
Paired T-test		***	***	***		***

This detailed analysis shows that there are differences in syndicate size according to sector of activity, irrespective of how we define syndication, and that syndicate sizes change according to sector specific risks. However, there are also clear differences between syndication levels in different regions, even within the same sectors. In the next section we consider how sector and regional variables influence the number of investors per firm.

7.4.8 Summary

We find that biopharmaceutical deals have a different syndication profile from other sectors, particularly when we look at the number of investors per deal. We have shown that biopharmaceutical deals are on average the most demanding deals in terms of the participation of different investors, generally having more investors per round. Although we find the numbers of investors per firm are less than those reported by Sorenson and Stuart (2001) for all US deals, and by Lerner (1994) for US biotechnology deals.

In our analysis we find some support for the financial motivation for syndication as the largest syndicate sizes are in the most risky sector. However, at the regional level we find differences in syndication are stronger when looking at total investor participation, suggesting certain regions have greater levels of participation regardless of sector. To understand the role of regional locations in influencing syndicate size we need to control for other factors. In the next section we report our results of the estimation of the model outlined in section 8.4. This will also help to understand the influence of specific locations and sectors on syndicate size, as we will be able to control for the range of other influences. In building the model we will also be able to evaluate different motivations to syndicate.

7.5 Results of the multivariate analysis

Table 8.7, over the page, shows the results of the negative binomial estimates of the model proposed in section 8.4. The table shows the results for the six variations in the structure of the model. For each included variable we show the coefficient estimate and the standard error in brackets. We also include the statistical significance of each coefficient, according to a z-test, at the 1% (***), 5% (**) and 10% (*) confidence level.

The table also reports summary statistics for each model. These statistics include the log likelihood and the likelihood ratio test for the statistical significance of the explanatory power of the included variables. As described in section 8.4.5, we include the results of the over-dispersion test, and the value of alpha. Finally, we show the results of the Wald (Testparm) and Likelihood ratio tests to show the relevance of the additional included variables compared to a base model, as indicated. The final line in the table shows the estimated value of *Total Invest* at the maximum syndicate size.

The results show the regional and sector variables are significant in explaining the number of investors per firm. Model 1, which includes the firm level variables, clearly shows that compared to firms based in the omitted region (*Midlands*) those located in either *Scotland* or *East* will receive investment from a larger number of investors. The coefficients of the regional dummies for Scotland or the East indicate that on average, firms in these regions receive investment from approximately two more investors than compared to a firm in the Midlands. We also observe a strong positive influence of *Biopharma* compared to the omitted sector *Other*, on the number of investors per firm. *IT*, *Comms* and *Healthcare* (*HC*), were also shown to increase syndicate size relative to *Other*, but had smaller coefficients than *Biopharma*.

As we introduce additional variables to the model we find the direction of influence of the group of investment variables is stable. However we notice in models 3-6, the size of coefficients of the regional and sector dummies are smaller than in model 1. The change in coefficient size indicates that other variables partially explain our observations made in Table 8.6. However, the statistical significance of dummies measuring firms in Scotland and the South remains consistent. Similarly, in models 3-6 biopharmaceutical firms remain associated with larger syndicates, even after controlling for additional factors. We also note that the influence of *Age at first invest* and *Founding* on the dependent variable is initially shown to be significant in model 1. However, as additional variables are added, their strength of influence and statistical significance is reduced.

Table 8.7 Results of negative binomial regressions (continued over page)

Model	1	2	3	4a	4b	4c	5	6
london	0.44251 (0.13095) ***		0.21125 (0.12892)	0.20215 (0.12456)	0.18587 (0.12378)	0.20462 (0.12533)	0.16993 (0.12890)	0.16790 (0.12665)
east	0.80527 (0.14295) ***		0.25565 (0.13965) *	0.30093 (0.13210) **	0.28833 (0.13142) **	0.28097 (0.13410) **	0.27167 (0.13517) **	0.24963 (0.13634) *
scotland	0.89578 (0.14114) ***		0.56384 (0.13623) ***	0.49010 (0.13100) ***	0.46847 (0.12935) ***	0.48186 (0.13409) ***	0.48029 (0.13967) ***	0.47172 (0.13477) ***
North	0.13416 (0.13950)		0.10941 (0.13584)	0.00702 (0.13222)	-0.02461 (0.13278)	0.01091 (0.13366)	-0.00531 (0.13934)	-0.00401 (0.13464)
South	0.54247 (0.12999) ***		0.31841 (0.12278) ***	0.36243 (0.11938) ***	0.35790 (0.11814) ***	0.37012 (0.11952) ***	0.33254 (0.12610) ***	0.33557 (0.12236) ***
Wales&NI	0.50281 (0.17879) ***		0.33233 (0.15367) **	0.15097 (0.14347)	0.13211 (0.14209)	0.12701 (0.14529)	0.11758 (0.17973)	0.09053 (0.14691)
IT	0.36004 (0.08030) ***		0.18692 (0.07948) **	0.17634 (0.07289) **	0.16854 (0.07323) **	0.18419 (0.07369) **	0.16775 (0.07342) **	0.17400 (0.07408) **
Comms	0.42538 (0.10608) ***		0.19060 (0.10475) *	0.13884 (0.10606)	0.12267 (0.10990)	0.14121 (0.10782)	0.12639 (0.10559)	0.12593 (0.10746)
HC	0.35037 (0.11478) ***		0.25038 (0.10734) **	0.25679 (0.09936) ***	0.25723 (0.09935) ***	0.24047 (0.10044) **	0.25623 (0.10961) **	0.24049 (0.10116) **
Bio	0.93203 (0.09653) ***		0.43117 (0.09384) ***	0.26777 (0.09163) ***	0.26438 (0.09231) ***	0.30759 (0.09382) ***	0.27698 (0.08794) ***	0.31441 (0.09370) ***
Age at first invest	-0.04507 (0.01209) ***		-0.00337 (0.01153)	-0.00426 (0.01079)	-0.00311 (0.01086)	-0.00536 (0.01099)	-0.00222 (0.01061)	-0.00290 (0.01110)
Founding	-0.02255 (0.00918) **		0.00307 (0.00880)	-0.00671 (0.00897)	-0.00554 (0.00896)	-0.00623 (0.00913)	-0.00578 (0.00780)	-0.00512 (0.00912)
No. of rounds		0.42163 (0.02451) ***	0.36615 (0.02292) ***	0.32970 (0.02138) ***	0.33188 (0.02155) ***	0.33832 (0.02151) ***	0.33419 (0.02099) ***	0.34293 (0.02157) ***
Total invest		0.02330 (0.00283) ***	0.02140 (0.00279) ***	0.01650 (0.00271) ***	0.01650 (0.00271) ***	0.01720 (0.00279) ***	0.01600 (0.00222) ***	0.01660 (0.00278) ***
Investsqr		-0.00009 (0.00001) ***	-0.00008 (0.00001) ***	-0.00006 (0.00001) ***	-0.00006 (0.00001) ***	-0.00007 (0.00001) ***	-0.00006 (0.00001) ***	-0.00007 (0.00001) ***
Quality		0.14173 (0.11062)	0.14995 (0.10834)	0.18565 (0.10019) *	0.17994 (0.10441) *	0.21291 (0.10025) **	0.18729 (0.10453) *	0.21164 (0.09951) **
Overseas				0.46122 (0.08871) ***	0.46936 (0.08909) ***	0.47265 (0.09094) ***	0.39784 (0.09725) ***	0.39824 (0.09895) ***
P_local				0.51440 (0.09029) ***	0.56155 (0.08832) ***	0.52873 (0.09098) ***	0.28934 (0.12776) **	0.26875 (0.13369) **
P_national							-0.30558 (0.12767) **	-0.35214 (0.12097) ***

Model (continued)	1	2	3	4a	4b	4c	5	6
Centrality				-3.47644 (1.26224) ***		-3.84328 (1.26905) ***	-2.52945 (1.60393) ***	-2.72043 (1.30184) **
Ave. portfolio_R1					-0.00021 (0.00014)			
Specialist				0.37731 (0.08413) ***	0.38407 (0.08466) ***		0.34882 (0.08323) ***	
Specialist_R1						0.27355 (0.12804) **		0.23997 (0.12776) *
Const.	44.79099 (18.36839) **	-0.51636 (0.07896) ***	-6.91195 (17.62518)	12.62199 (17.96075)	10.25004 (17.93362)	11.63942 (18.28132)	11.00223 (15.60828)	9.69219 (18.24680)
Loglikelihood	-2527.03	-1445.75	-1423.85	-1377.3	-1368.01	-1384.4	-1374.78	-1380.69
Obs	1562	1013	1013	1013	1004	1013	1013	1013
LR model test	204.34 ***	496.1 ***	540.41 ***	633.51 ***	622.55 ***	619.32 ***	702.99 ***	626.74 ***
Compared to model:	n/a	n/a	2	3	3	3	4a	4c
Testparm			46.26 ***	95.76 ***	92.61 ***	79.98 ***	5.73 **	7.55 ***
LR test			43.8 ***	93.11 ***	n/a	78.91 ***	5.64 **	7.42 ***
Maximum £M	n/a	130	135	128	129	128	125	126

In model 2 we include variables measuring the characteristics of each investment. The results show that *Rounds* and *Total invest* positively influence the dependent variable. This result indicates increasing either the number of rounds or finance a firm receives determines a larger number of investors. The coefficient of *Total invest* is relatively small compared to *Rounds*. For example, keeping other factors constant, the number of investors increases by 2% for each additional £1m of investment²⁷. If we increase the number of rounds by one, it is expect to result in approximately a 30-50% increase in the number of investors.

The size and direction of influence of *Round*, *Total invest* and *Investsqr* are consistent in each of the models 1-6. We note that *Investsqr* is shown to be significantly different from zero, but negative. The reverse is found for *Total invest*. Our final observation for the investment level variables is that *Quality* is not shown as significant. As we develop the model by including additional variables, we find that the quality of the deal becomes significant, although the size of the coefficient is relatively stable across models.

²⁷ This approximate rate is similar to that reported in Guler and McGahan (2006) for a linear relationship of finance to the number of investors

In models 4a, b and c, we introduce variables measuring characteristics of the investors in each syndicate. The estimation results for these models show that either the presence of an overseas investor (*Overseas*), or a higher proportion of local investors (*P_local*), increases the number of investors in a particular deal. For example, keeping all other factors constant, a firm funded by only local investors is associated with around a 60% larger syndicate, than a firm not funded by any local investors.

In Table 8.7 we find that the influence of *Centrality* on the number of investors is consistently negative. In models 4a, 4c, and 6, *Centrality* is statistically significant, indicating that including investors with a central network position in a syndicate will reduce the overall number of investors. In model 4b we exchange *Centrality* for *Ave_portfolio_R1* as both variables cannot be included in the same model. Although both variables show the same direction of influence, the average portfolio of investors is not shown to be statistically significant.

The results in Table 8.7 also show that specialist investors increase the size of syndicates. The presence of a specialist investor is also shown to be a statistically significant influence on the number of investors in models 4, 5 and 6. We also find that comparing model 4a and 4c we find the size of the coefficient of *Specialist_R1* is smaller than *Specialist*, indicating that when the specialist is involved in the first round of investment syndicates maybe slightly smaller. Our final step, in model 5 and 6, was to include *P_national*, a measure for the proportion of national level investors financing a firm. We find introducing the measure of national investors negatively influences the number of investors.

7.5.1 Discussion of results

The results show strong support for the variables included in the model. Every group of variables is accepted as having explanatory power. However, we find that compared to our expectations there is some variation in the direction of influence of variables.

We find that the sector dummies reflect our expectation that biopharmaceutical investment requires larger syndicates, supporting the financial risk hypothesis. However, we also find that specific locations are shown to be more likely to have larger syndicates, which goes against the expectations made by the financial risk motivation. In fact we find the value of coefficients of particular regional dummies are greatest in regions with significant investment activity indicating that greater access to investors is a feature of high

performing locations. The importance of specific locations in determining syndicate size supports our discussion of the value adding and information sharing perspective.

We find that *Round*, *Total invest* and *Investsqr* corresponds with our expectations and support a financial risk motivation for syndication. Our findings also support presence of a quadratic relationship between the number of investors and the amount of finance received. The presence of a quadratic relationship means we can interpret the coefficient of *Total invest*, as representing the gradient of relationship between the two variables at the point when investment = 0, (i.e. the slope resulting from $\Delta\text{Total investment} = 1$), and the coefficient of *Investsqr* as the rate at which the gradient of *Total invest* diminishes with increasing investment (Wooldridge, 2003). Therefore the maximum number of investors is estimated to occur in the range of £100-130m of investment²⁸. We note that this level of financing is generally out of scope for this research which is focused on early stage financing, indicating that the relationship is approximately linear in the early stage investment context.

We also find that the quality of the deal is not a consistent predictor of the number of investors per firm. As our correlations show that *Quality* is not particularly strongly associated to other variables, including the number of investors, we have two possible explanations. Firstly, that our result reflects the inherent difficulty in selecting the right deal; the quality of a deal only becomes apparent in the final stages of an investment. This means once we have controlled for the amount of investment and number of rounds the quality of the deal has only a small effect on the number of investors involved. This may also explain the positive coefficient value, as investors are attracted to successful deals in the final investment rounds, as per Lerner's (1994) collusion hypothesis. An alternative explanation for the result is that our measure of deal quality is noisy. For example our measure of exits may be affected by the turbulence of the internet bubble. This explanation is supported by the negative statistical correlation of *Quality* with *Founding* (i.e. high quality deals in earlier years) and a positive correlation with *IT*.

The results for the influence of overseas investors and investors with central network locations matched expectations. The results for both factors support the presence of financial risk motivations to syndicate. However, other investor level variables did not behave as predicted. For example the results for the proportion of local and national

²⁸ A similar result obtained using OLS

investors in a deal, indicate they influence the number of investors in the opposite direction to our expectations. One explanation for this result is that our geographical coding includes additional information such as the size of an investor. For example an investor who operates nationally maybe larger than an investor that operates in only one location. This is supported by the correlation analysis, where we find that the proportion of local investors in a deal is negatively correlated with the size of average portfolio of investors. The reverse is found for the correlation of the proportion of national investors. This help to explain our result in Table 8.7, as investors with small funds would need to syndicate more than those with larger funds.

Finally, we find that the results of the influence of a specialist on the number of investors are also opposite to those expected. We expected to find that specialist investors would reduce syndicate size, given their in-depth knowledge of the sector. In fact, we find that our results support Bygrave (1987), that specialist investors are invited to join syndicates by others investors to gain from their experience and knowledge, resulting in larger syndicate sizes. This also explains the finding that coefficient of *Specialist* is larger than *Specialist_R1*. The involvement of a specialist early in a firm means that their knowledge can help to reduce the need for additional investors.

7.6 Conclusion

In this chapter we have demonstrated that syndication is a significant part of early stage investment activity in the UK. As suggested by the literature we have found that financial risk considerations, such as the level of finance, the number of rounds and sector specific risk influence the size of syndicates.

As biopharmaceutical investments are high risk, syndicating reduces financial risk. This chapter demonstrates that biopharmaceutical firms require larger syndicates than for other sectors. One possible implication of this observation is that biotechnology firms must offer large potential returns to satisfy obtaining a large syndicate of investors.

Despite controlling for a range of variables, regional variations are persistent. Firms in the South, East, and Scotland are more likely to receive investment from a larger number of investors. These regions still outperform when additional investor characteristics (i.e. characteristics of investors in these regions) are introduced and sector specific risks controlled for. We also note that the prominence of these three locations agrees with the size of the fixed effects coefficients in Chapter 6. Although we conclude that financial risk

motivations are the primary cause for syndicating, we suggest that regional variations provide evidence for non-financial factors that encourage syndication and greater investment activity. We suggest specific locations connected with strong investment activity, act as quality 'labels' encouraging investors to seek out syndicates in these locations to access investor experience, knowledge and information. We also find that syndicate sizes are increased by including specialist investors who bring valuable experience to a syndicate.

Our review of the literature has also indicated that syndication is a portfolio level management tool. This indicates that it is important to view investors in the context of their portfolio of investments, rather than a single investment. We have noted in Chapters 5, 6 and 7 that we believe networks to be a critical part of the functioning of venture capital. In this chapter we have found that investors are motivated to join together to reduce risk, and to share information and valuable expertise. This chapter also confirms that syndication has important consequences for access to future opportunities and investors and supports our network analysis in Chapter 7.

In this analysis, like in Chapter 7, we found that centrally networked investors and national investors were related and both these factors reduced the need for firms to have large syndicates. However we have also found syndication activity to vary according to location. Investor's preference to finance firms in specific locations contributes to a concentration of interactions between investors in geographical space. This suggests that although syndication networks overall are organised by national actors with national coverage, syndicate dynamics have a regional component and investors prefer to form larger syndicates in firms where investment is most concentrated. Whilst key investors can finance firms across the UK, their preference is to concentrate on a few key locations and participate in larger syndicates. Finally, as we find that network measures reduce the importance of regional dummy coefficients, we conclude that networks play a role in supporting locations. After controlling for the role of networks in transferring information and knowledge, the regional coefficients provide a measure of the quality of the information and knowledge associated with these networks and the people involved. In the next chapter we start our analysis of relationships between actors more closely associated with the demand for investment.

8 Entrepreneurial firm directors

8.1 Introduction

This chapter investigates the role of social networks form by relationships between directors of entrepreneurial venture capital backed firms. Here our aim is also to understand the influence of regional location on the formation of relationships between key actors in the entrepreneurial process, firm directors as outlined in Chapter 3. Therefore, this chapter continues to examine the role of networks in venture capital.

In the early stages of a firm's development, direct support is given by the entrepreneurial team. We focus on company directors as those who are expected to have important influence over the strategic development of the firm. In Chapter 3 we emphasise the importance of individuals with 'business scan' gained from multiple experiences of entrepreneurial firms that can be put to use to help guide the strategic direction of the firm. As new start-ups are generally resource poor, the firm's directors can play an important role, ensuring that the firm's resources are used efficiently as well as supporting the firm providing finance and non-finance resources such as useful contacts.

Given our discussions of entrepreneurial networks in Chapter 3, social capital is an importance resource for the success of the firm. Our discussions of social capital in Chapter 3 also tell us that the most valuable directors will be in demand by many firms and have the option to sit on several firm boards. Directors in demand are commonly associated with other 'in demand' actors. Therefore we can expect the social network of directors to represent structural and relational social capital relevant to the study of venture capital and entrepreneurial firms.

In this chapter we specifically look at the directors of biopharmaceutical entrepreneurial firms. We have previously noted that the challenging field of biotechnology it is expected to have a high demand for experienced professionals, whilst in the UK the availability of expertise in managing biotechnology SME is expected to be low. A pool of experienced managers with start-up expertise helped to develop the Cambridge area; but the availability of this expertise is lower in other regions (Papaioannou, 2006).

The long transition from academic lab to established break-even biotechnology company adds complications to the traditional venture capital process. The need to obtain and manage the significant funding required for this transition, dictates the need for specialist

expertise in the entrepreneurial process. The type of expertise required includes a range of specialist skills related to activities such as strategic partnering, managing access to finance and preparing the company for flotation or sale. Additionally, as most biotechnology firms start life without a product or knowledge based service ready for market, there are additional requirements in terms of the need to manage the innovation strategy and development of products and services.

In Chapter 3 we also indicate that VCs are associated with providing specialist director expertise, and can be expected to participate in director networks. However, the UK VC industry has frequently been criticised as demonstrating a lack of technology awareness, experience, or willingness to experiment with emerging technologies. The logical explanation given is that UK venture capitalists do not have the necessary technical or scientific experience to take an effective hands-on role in the commercialisation of UK scientific innovation. This view places an emphasis on the venture capitalist in both the assessment and support of entrepreneurial business. By choosing to look at business funded by venture capitalists, it is possible to investigate the type of directors found in entrepreneurial high growth firms.

We investigate to what extent directors of venture capital backed biopharma SME are connected and to what extent they take positions in the same firms, or in the same locations. This helps us to understand from a regional perspective, how social networks of directors relate to the development of regional biotechnology activity. We begin by briefly reviewing the background literature on the role of directors and director interlocks. Then we focus specifically on the few studies of director networks in the SME environment. Finally we analyse our director networks looking for the presence of key actors, their regional distribution and career backgrounds.

8.1.1 Role of directors and interlocks

In general Johnson, Daily and Ellstrand (1996) review the literature on board director's and categorise three types of roles that directors can be expected to fulfil. These are:

1. Control; which includes the monitoring of management to ensure the firm is run in the interests of the stockholders, and other related activities such as the appointment of the CEO.
2. Servicing; to act as support and advice to the CEO and management team and,
3. Resource dependence; that boards are a means for "facilitating the acquisition of resources critical to the firm's success" (Johnson et al, 1996. p.411).

Similarly, these roles can also be related to the situation when a director sits on two firm boards, creating as an interlock. For example an interlock can reflect a director's role in generating resource dependence between firms. The appointment of a director from an investment company to a firm's board may provide potential access to financial capital. Analogous to our discussions in Chapter 3, for small firms, gaining access to critical resources can be the key to firm survival. The lack of "historical legitimacy" in start up business may also make the appointment of directors from prestigious firms important (Mizruchi, 1996).

In resource dependence, an interlock represents a means of accessing firm resources (Boyd, 1990). This perspective represents organisational interests rather than the director's personal ones, which infers that organisations are the social actors, and the patterns of linkages represent inter-organisational dependence and constraints (Pfeffer, 1987 p.40). However, small firms, compared to larger firms, have fewer options when it comes to the selection of their directors. Small firms may not be able to select directors according to firm level organisational resource dependency preferences (Pfeffer and Salancik, 1978).

Resource sharing is also likely to involve some form of co-operation and monitoring activity (Mizruchi, 1996). For example interlocks can represent a controlling role when a large institutional shareholder appoints one of its own directors to monitor the board and have influence over key decisions. Directors may also be appointed to provide a service, such as guidance to the other board members (Johnson et al, 1996). The 'servicing' role of the board directors has also been shown to be important for CEO's of SME, particularly that an outside director can provide a breadth of guidance and advice to the management team (Daily and Dalton, 1992, 1993). In many cases the CEO supports the help of outside directors (Rosenstein et al, 1993. Deakins et al, 2000). Additionally, Deakins et al (2000) see the supporting activities of the non-executive as a method of entrepreneurial learning for the entrepreneur who is advised and guided through the development of their business.

However, the service role of interlocks is not necessarily guided by firm level motivations. In SME, it is likely that the motivations of the interlocking director are closely aligned with their own career choices and professional development. Therefore, in the servicing role, a director may represent their own interests or those of another firm.

Nicholson et al (2003) suggests that understanding the motivations of individuals creating the interlock is also important. In contrast to purely organisational motivations for creating director interlocks, Boyd (1990) observes that high performing firms use fewer directors, but choose those who “are most densely connected to the environment” (p.428). Here we see a dual property of interlocks, that aside from connecting firms, the qualities of the director are important.

The literature on interlocks provides alternative perspectives on individual motivations for interlocks. These perspectives include elitism and career development. The elitist perspectives suggest that interlocks are a result of social cohesion within an elite capitalist class, for example they represent the interests of wealthy families (Pfeffer, 1987) or clubs of elite directors, and potentially associated with collusion (Bazerman and Schoorman, 1983). However, reflecting our discussion of social capital theory in Chapter 3, Kono et al (1998) note that ‘clubby’ behaviour can have positive benefits providing a means of maintaining trust, which helps these individuals share information and work together. Although Conyon and Muldoon (2006) found that interlocks in US firms could generally be modelled as a random network, they found some evidence of elite groups of directors in parts of the network where in-demand directors, sat on boards of similar in-demand directors.

The career development perspective proposes that interlocks are simply the result of an individual’s aspirations to gain exposure to new business situations, contacts and prestige (Zajac, 1988; Useem, 1984 cited Mizruchi, 1996). Like in the elitism model, the career development perspective emphasises that interlocks are important to the individual director. The firm is still a beneficiary of the interlock, potentially gaining access to the very social capital and resources that the director has accumulated through their career. This presents an interesting situation where communities of individuals develop, defined by their history of involvement with firms, but formed from director’s own independent choices.

8.1.2 Geography – directors, interlocks and social networks

We know from our discussion of the literature in previous chapters that the propensity to form social ties reduces with distance (Sorenson and Stuart, 2001). Similarly, geography can also be seen to influence the formation of interlocks. For example Green (1983) found that interlocking between cities reduces with the distance, whilst O’Hagan and Green (2004) found that US and Canadian firms with headquarters in the same location were more likely to have interlocks.

However, Kono et al, (1998) finds that the nature of interlocks changes with distance between firms. They find that firms based in the same location share interlocks based on intense relationships between directors, indicating the presence of elite director clubs. The proximity of the firms created the opportunity for frequent contact between local directors, facilitating the creation of strong bonds and trust which “lay the foundations for local interlocking” (p.896). They also found that directors of the most successful firms were more likely to be found on the boards of other firms.

However, over longer distances the interlocks were motivated by resource dependence, particularly when financial resource dependence was involved (Kono et al, 1998).

O’Hagan and Green (2004) found that non-local interlocks were used to access locational specific resources. For example, firms based in large cities were often interlocked with firms in smaller cities to provide access to corporate specific knowledge.

8.1.3 UK SME director networks

The UK studies by New (2003) and Myint et al (2005) focus on the role of key serial-entrepreneurs and networks connected to bio-clusters in Cambridge and London. Myint et al (2005) identify mini-clusters relationships in the network of directors of Cambridge University spin out firms. The authors find strong patterns of repeat connections between directors of SME firms indicating strong structural and relational social capital in the Cambridge region. The authors note the absence of founding scientists in the successive management of firms; instead they observe that, “*the majority of high technology companies that have shaped the success of the Cambridge cluster are connected to a handful of serial entrepreneurs, business angels and venture capitalists*” (p.169).

Significantly, Myint et al (2005) note one of the most important factors in the development of mini-clusters is “a history of working for a common company” (p.2005). In agreement with Stuart and Sorenson, (2003) and Sorenson and Stuart (2001), a shared history has benefits for the directors in terms of training, sharing of tacit knowledge important for entrepreneurship and attracting investment. The clustering of directors in a single location is linked to Stuart and Sorenson (2003) observation that owners and founders favour operating in areas where they have social networks, indicating the strong presence of regionally based social capital.

In agreement with the view of regionally based social capital, Garnsey and Heffernan (2005) find that the development of the Cambridge region was a cumulative generational process, where social capital features strongly. In this process, waves of entrepreneurs start firms and recruit local people to work in their businesses. These waves of recruits have since generated spin offs business, and in so doing created a network of experienced businesses capability located in the region, built on mutual knowledge and trust.

In contrast to Cambridge, New (2003) finds fewer “key individuals” operating in the London cluster, potentially as a result of the strong history of biotech in Cambridge. According to New (2003) London has yet to acquire a critical mass of biotechnology firms and supporting entrepreneurial actors. We look at the detail of these issues in Chapter 10.

8.1.4 Which perspective is appropriate?

Our discussion of the literature on social networks generated from director affiliations to firms has demonstrated a variety of perspectives in this field. The focus of the interlock literature is mainly on large corporate firms and their boards, whilst literature on SME firms focuses more closely representing the social capital of directors. We find both literatures discuss variation in ties according to geography.

Our literature review has demonstrated a variety of explanations for ties between firms based on interlocked directors. Although different perspectives can be combined in a complementary way, for example Mizruchi (1996) suggests that the career development perspective complements any of the inter-organisational views of interlocks.

We also find literature which focuses on director motivations to form interlocks, such as career development and elitism which resonates with our discussions of social capital in Chapter 3. The focus of this thesis is on SME firms with limited resources. We include the firm’s directors as an important SME resource. In this way the ability of an individual to fulfil the role of director, i.e. their ‘business scan’ is linked to their contacts, status and ultimately their social capital. A network formed from the affiliation of directors to different firms, represents director’s career development, but also creates ties between different directors which is indicative of the accumulation of social capital, as per Cohen and Fields (1999). In the SME environment we suggest that the career development perspective naturally complements social capital theory as we have discussed in Chapter 3.

Similarly, our discussions of elitism in director interlocks correspond to the concepts of mini-clusters and structural and relational social capital discussed in Myint et al (2005). Interlocks have been shown to reflect elite groups, where ties are strong between high performing and powerful directors. We argue that elite groups of SME directors will be strongly tied. For example, following our discussion of social capital and embeddedness in Chapter 3, important directors can be expected to accumulate high levels of social capital which potentially encourage the formation of strongly tied directors. Here we emphasise that repeated relations between directors indicate a pattern of interaction which helps these directors work together and form trust. It also suggests the presence of ‘clubs’ of directors, formed from the most active directors in the sector.

Finally, we find agreement in the literature regarding the effects of proximity. Firstly we have found that interlocks cluster in terms of social and geographical space. On a local basis the interlocks were driven more by individual level motivations, such as career advancement and elite clubs. Both Myint et al (2005) and New (2003) conclude that ties between key individuals with the experience and local connections help to develop businesses represent the formation of strong regional social capital, essential for the progress of bio-clusters.

Over longer distances interlocks tend to represent inter-firm networks driven by motivations to access resources within other attractive firms or locations. We might expect relationships formed across regions to have different characteristics from local ties. We can expect long distance ties to be more targeted, with an absence of the presence of mini-clusters. It also follows that locations with concentrations of influential directors should be targets for other firms based in other regions, to provide access to the director’s resources, as well as wider regional resources.

We have also noted that some directors in our network are expected to be investors. As investors are likely to represent an investment firm’s interests, this clearly complicates their role as a director. A venture capitalist can be seen as interlocking the firm and the investment fund, acting in combination of a monitoring, servicing and resource dependence role. However, the investor’s skill at working with start-ups will also depend on their ‘business scan’ and ability to build relationships with other influential directors. So in this sense neither the career development nor elitism perspective is restrictive.

Based on this literature review we should expect that the formation of director networks is likely to be associated with the development of UK regions. Extending this argument we can expect that local networks will vary according to the specifics of their regional context and available director experience. Furthermore building on the argument that social networks operate locally, means that key individuals are locationally constrained and operate in a limited geographical area, further re-enforcing local concentration of director activity.

In summary our review has generated a set of expectations regarding the structure of networks formed between directors who share affiliations to SME firms. We can expect ties between directors within the same regions to be concentrated and motivated by individual career development choices. We can expect that ties across regions are more dispersed, representing more formal interactions between directors. We expect to find investors provide an important indicator of the function of social networking between directors. For example, as we find in Chapter 7, investors search for the most profitable firms encourages them to operate over larger distances and create network links across locations. However, if benefits from regional director networks are strong we will find investors attached to elite groups of directors.

8.2 Method

8.2.1 Representing networks

We are interested in analysing the social ties of directors with experience of multiple directorates; to do this we build a network from the affiliations of directors to firms. The affiliations of directors to firms can be represented as a two mode network (firms and directors). However, we are motivated by the analysis of the ties between groups of multiple boarded directors (1 mode representation). Rather than understanding an individual's motivation for interlocking any two firms, we analyse the structure of relationships between in demand directors, or an elite director groups. By analysing the social network of this elite group we analyse the structural and relational social capital of these directors. It follows that well connected directors with more experience will have developed greater social capital which can be applied to the start up firms.

Mapping the involvement of directors and firms, without limiting the network to concurrent directorships creates the opportunity to show the full association of relationships between individuals and firms. In interpreting the network, it is important to be cautious in assuming that two individuals linked to the same firm would have

knowledge of working with each other. For example, they may relate to different periods in time, or in fact one may be the replacement for the other. We are interested in understanding the pattern of interactions, and therefore consider the networks as cumulative process of building relationships between directors.

If we were to represent the 1 mode director network as a sociogram, it would be very dense. Such a representation uses all relationships between directors; therefore each director on a firm board is automatically connected to every other director who has been attached to that firm (Conyon and Muldoon, 2006). Therefore, even a director who has only sat on one firm board is shown with several relationships to other directors (the directors of the same firm).

Our motivation in constructing a sociogram is to highlight directors who repeatedly take positions on multiple firm boards. Therefore rather than represent all connections, we simplify the network structure to include only directors involved in creating linkages between firms. This simplification helps to show a structure involving key individuals with multiple external links, as opposed to many ties internally generated from being a member of one firm with a large board.

We achieve this 'reduced' 1 mode representation by modifying the 2 mode network. In the two mode network (directors and firms) we exclude directors which sit on only one firm board. We transform this reduced two mode network into a 1 mode director only network, which represents relationships between serial or multiple affiliated directors.

8.2.2 Analysing networks

The network can be analysed in terms of the overall pattern of co-ordination and observable sub-groups. We use social network analysis, as described in Chapter 4, to represent the networks as sociograms, using Pajek (De Nooy et al, 2005). As in Chapter 7, we analyse the network to determine the structural properties of the network, as well as highlighting the presence and position of key actors. Social network analysis provides an unbiased means of identifying network co-ordinators (Castilla et al, 2000).

Following our discussion of the career development perspective, the expected prominence of investors, and the role of geography in determining the structure of networks, in our analysis we categorise directors according to their career background and geographical preferences. Director's career backgrounds highlight the role of particular types of director

in the network, whilst directors locational preferences, based on the location of the firms where they have a director position, indicate geographical patterns of activity and aid our interpretation of the network structure. We describe how the career and locational data is obtained in the data section.

A common critique of network research is that the analysis is often based on a single type of relationship. For example, Myint et al (2005) suggest using director appointments provides a limited method for tracking other forms of relationships important for supporting entrepreneurial firms, such as support from advisors and or more informal types of relationships between people. These other relationships may also have value and reflect social capital. However, the alternative to view all types of relationships between individuals has obvious practical limitations. It is difficult to collect and analyse data on a multiplex of relationships. As we discuss in the following section, we expand our analysis to include an analysis of cumulative relationships between directors formed by affiliations to the same firm, rather than restricting relationships to concurrent ties, to provide a more encompassing perspective of relationships between directors.

Finally, we also improve on previous studies by examining the relationships formed between directors in four UK regions. We also consider the ties between the four regions. However inter-regional ties must be assessed cautiously, as without the full population of UK directors, from all regions, inevitably some director's ties to other regions can be missed. As we note in Chapter 3, a minority of actors can have a large impact on network structure; the same applies for missing ties. This means we cannot treat our analysis as representative of the UK overall. Our findings should be interpreted as firstly an analysis for four regional networks, formed of directors of firms in each respective region, and secondly as indicative of ties between each of the four regions.

8.2.3 Networks and cumulative structures

The use of a cumulative network structure, as described, is different from the strict application of director interlocks. As we do not restrict the relationships in the network by the timing of particular director appointments, a relationship can exist between directors who have been at the same firm, although over different periods.

We justify a cumulative network structure on practical and theoretical grounds. Starting with the practicalities, we observe a set of biopharmaceutical firms over a relatively short period of time. As we indicate in Chapter 4 the majority of firms in the dataset are

founded between 1998 and 2006. Therefore, we assume that the histories of firms in the database are fairly short and it is likely that directors of these firms will have an awareness of the other directors that have been involved in the same firm. This is also supported by the average duration of a director in a particular position being over 3 years²⁹, suggesting the appointment of directors is not made on a short term basis.

A final practical point is that dates of formal appointment to the board represent a legal status, rather than a social relation. For example, director appointments are an important part of managing a SME. Appointments are carefully considered to gain the necessary trust between the other board members. The appointment of a director is likely to be a final step in the process of building a relationship between directors, such that social or informal relationships will start well in advance of any formal appointment. Similarly, even after stepping down from a board, a director's social relationships to other board members may persist. In summary, it would not accurately reflect the social networks between investors to strictly apply concurrent interlocks.

From a theoretical perspective, in the dynamic environment of entrepreneurial firms, relationships between individuals are expected to be less restricted by the boundaries of firms and more closely tied to 'group' identity (Saxenian, 1991). In this case the common identity is that of directors of start up firms. The historical accumulation of social capital and the career development perspective both indicate that it is beneficial to follow the development of linkages, rather than only view relationships as a snapshot. As the entrepreneurial context suggests, relationships should be viewed on a personal level, and extend beyond the formal timelines of being a director at a firm. This perspective of persistence in informal ties, is supported by Granovetter's (1973) work on infrequent or weak ties, as well as research demonstrating the importance of previous associations, such as shared affiliation histories (Myint et al, 2005). Therefore relaxing interlocks to more general accumulation of director affiliations is appropriate.

8.2.4 Data

Our analysis is based on the director firms in four UK regions; East, London, Yorkshire, and Scotland. We use the Library House dataset of biopharmaceutical firms receiving venture capital funding between 2000 and 2006, and information from FAME on director positions, to construct a relational database comprised of the history of board directors of biopharmaceutical firms. To aid our interpretation of this data we include details of the

²⁹ The actual duration of a director in a firm is likely to be longer, as some directors included in the database as moving roles e.g. from CEO to CTO or CFO.

firm's location, type of business, academic origins, and sources of funding. As described in Chapter 4 we also use information on director profiles, for example their qualifications, commercial experience etc, to improve the detail of the analysis.

Directors are categorised according to their expertise based on the information we collect. We generate five categories according to whether they are acting as a venture capitalist, entrepreneur, consultant/advisor, professional director, or fall into the remaining 'other' category. We identify venture capitalists as working for a venture capital firm. Consultants and advisors include those individuals posting active involvement in consultancy and accountancy or legal firms (rather than by qualification). Directors connected to serial board positions, but without detail of involvement in founding or investing, are described as professional directors typically taking executive positions within companies. Finally, those directors who cite being a founder or entrepreneur, but without association to being a venture capitalist are coded entrepreneurs. A small remainder were coded as 'other', because they either act as company secretary or their details were not possible to obtain. We also collect information on the qualifications of the directors, according to whether they have accountancy, legal, PhD or MBA qualifications.

The geographical location of each director is based on their affiliations to firms. For example, a director who served on the board of firms in one region is attributed to that region. If a director sits on boards of firms in different regions, then they are considered to be multi-regional.

Finally, one adjustment is made to the director data as a result of changes in the ownership of firms. A consequence of looking at the construction of linkages over time is that the sample of firms is subject to change, as firms can be acquired by other firms. We stop tracking the directors of businesses which become acquired by large multinationals, as multinational firms are not the focus of this analysis. In a small number of cases, a firm in the database is acquired by another venture backed firm. In order to keep the analysis clear, for these cases we include all the directors involved in both firms, but record the firm by its most recent name.

8.3 *Some properties of director networks*

8.3.1 Skewed distribution of relationships

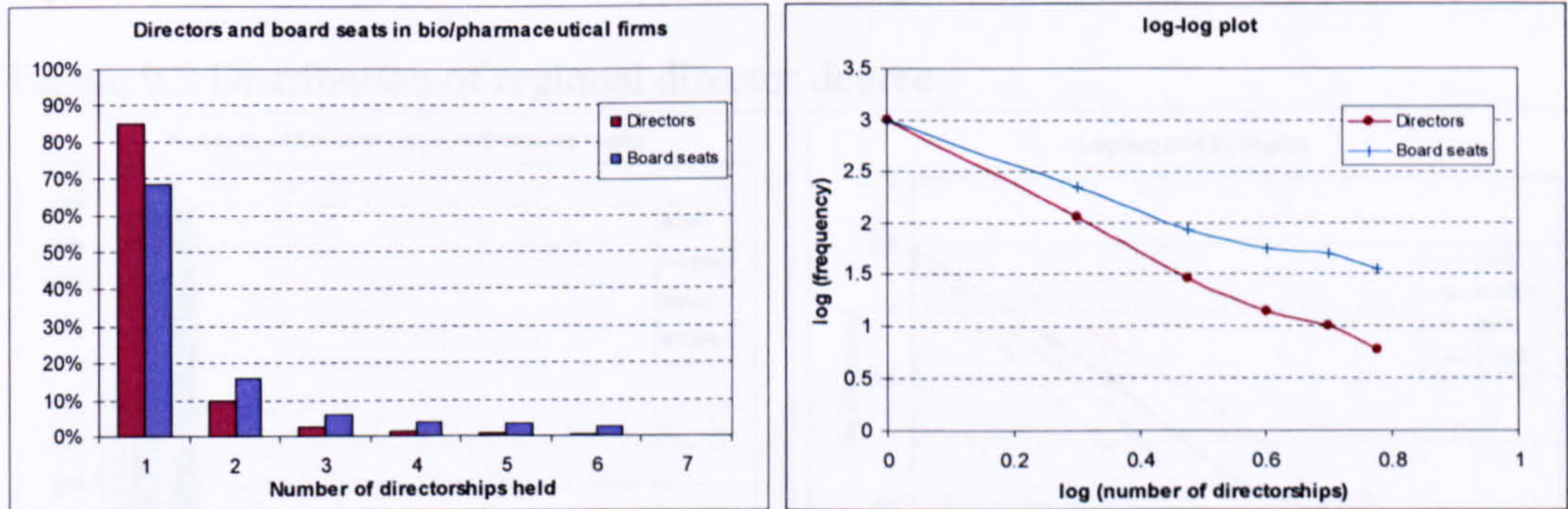
Before we look in detail at the structure of networks, we first examine the data on directors to see how many individuals have served on multiple boards. We can also see how many

of the available board positions in firms are taken up by these multiple boarded directors. In total we find in our sample of 108 firms, that 1152 individual directors account for 1434 board positions³⁰.

Figure 9.1 shows the distribution of all directors and board positions in the four regions according to the number of directorship affiliations a director has. We can describe this graph as capturing the degree of directors (when the network is in 2 mode form) (De Nooy et al, 2005). It shows that approximately 85% of individuals sit on only one firm board. These directors account for 68% of the total available board positions in the firms in our sample. Directors with multiple affiliations only account for a small minority of the directors in the sample, but because they are active in several firms, they have a larger impact. For example only 0.5% of directors have six board affiliations, but they are involved in 3% of the total board seats.

Overall, the 15% of directors with multiple affiliations represent 32%, or approximately 450, of the available board seats. On average each multiple affiliated director has 2.6 board positions, where each board position is in a different firm. This means, when we look at directors with multiple affiliations, we are focusing on a small minority of individuals with a particularly high level of representation in the bio-pharmaceutical sector.

Figure 9.1 Distribution of director degree



Graph (left) above chart the proportion of directors and boards seats held against the number of affiliations of directors. The line Graph two (right) shows the log of the frequency of board seats and directors plotted against the log of the number of affiliations of directors.

The most striking aspect of Figure 9.1 is that the frequency of directors (and the board seats they fill) falls rapidly as the number of affiliations is increased. It suggests and an exponential decay trend or the presence of a power law. The presence of a power law in a one mode network has associations to the type of distributions found in a hub based or

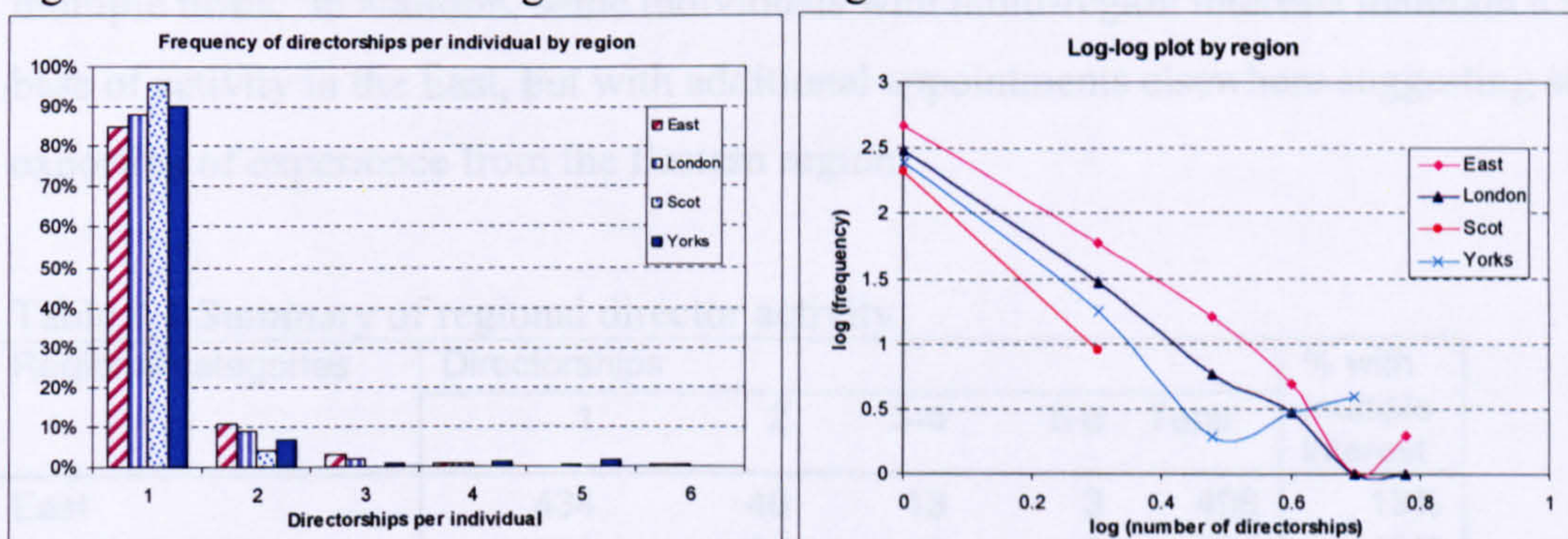
³⁰ In total 1472 board positions are named, but 28 are removed as they result from the renaming or merging of companies. We do not count multiple board positions held by an individual in one firm.

preferential attachment type network, which can be demonstrated by plotting the frequency data on logarithmic scales. We find the lines on the graph on the right are approximately linear on a log-log plot and therefore are suggestive of the presence of a power law. Although, as in Chapter 7, we note that the distribution of the data is too narrow to confirm the presence of a power law. However, this analysis shows that highly connected directors within our sample are rare, and likely to strongly influence the structure of the network of directors.

Figure 9.2 repeats the analysis of Figure 9.1 for directors based in each region. In all regions the directors with multiple interests are the minority. The Eastern region has the highest proportion of multiple board directors and Scotland the lowest. Scotland also has the smallest range of directorships per individual; they have no directors involved in more than two biopharmaceutical firms.

Similarly the log-log plot of the count of director degree for each region shows a consistent linear gradient for each region. As in Figure 9.1, we find that well connected directors are a minority within each region. Although Scotland is clearly limited by the lack of any directors with more than two directorships in the data collected. A final observation is that for a minority of well connected directors, particularly in Yorkshire and the East, the frequency of these individuals is greater than suggested by a simple power law relationship.

Figure 9.2 Distribution of regional director degree



Graph (left) shows the regional histogram of the frequency of directorships per individual. In graph (right) the data is plotted in log-log form.

One possible explanation for the higher than expected number of high degree directors in Yorkshire and the East, is the presence of organised director clusters or a managed pattern of interaction between the key directors. For example, Conyon and Muldoon (2006) observations of homophily in directors suggests directors prefer to group with similar

performing directors. In this case, well connected investors may prefer to sit on the same boards as other well connected directors in the same location.

As we measure the connectivity of directors differently from previous literature we cannot compare our results directly to other large firm studies. Our results suggests that at a national and regional level, relative to the total number of directors, only a small proportion of directors are active across multiple firms in the same sector. However, do our results suggest a national level of organisation, similar to that found in Chapter 7, or do the results indicate distinctive groups of regional actors?

8.3.2 Regional co-ordination: Links between and across regions

Next we adjust our data to account for directors who work in many regions. Table 9.1 is a summary of the number of individual directors categorised according to their geographical coverage and the number of directorships held. Table 9.1 categorises people in the dataset according to whether their biopharmaceutical interests are based purely in one region, or more evenly spread across multiple regions. For example it shows that there are 496 individuals who only serve on boards in the Eastern region, of which the majority 434 had links to a single company. In the East 13% of directors had multiple interests and a small minority had a history with 5 or more firms in the region.

The East has the greatest number of people with experience of acting on a biotechnology-pharmaceutical firm’s board, but also a greater number of people with experience of multiple firms. In addition, some individuals with multi-region interests maintain a strong base of activity in the East, but with additional appointments elsewhere suggesting some exporting of experience from the Eastern region.

Table 9.1 Summary of regional director activity

Regional categories	Directorships					% with multiple interest
	1	2	3-4	5-6	Total	
East	434	46	13	3	496	13%
London	261	26	8	2	297	12%
Scotland	185	4	0	0	189	2%
Yorkshire	101	4	2	2	109	7%
Multi region (2)		32	14	3	49	100%
Multi region (3)			6	6	12	100%
Grand Total	981	112	43	16	1152	15%

Chi-square test comparing proportions of multiple affiliated regional directors for the four regions only (i.e. top four rows of table) to null hypothesis of no difference from the proportion for the total is rejected (pval = 0.001)

For the remaining regions, London had the next highest number of directors, and 12% of directors with multiple interests. Scotland and Yorkshire have very low levels of multiple directorships, suggesting the absence of locally embedded experience specialising in managing biopharma businesses.

Scotland and Yorkshire have a much greater reliance on those individuals shown to have multi-regional interests. These are shown by the categories named as, “Multi region (2)” and “Multi region (3)”. The directors coded as multi regional have a distribution of interests across several regions. These individuals provide connections between businesses across regions and signal the need to examine the overall interactions between all firms. The presence of multi-regional directors indicates that the network features highly connected directors who operate at a more national level, as well as directors whose activities are concentrated in one region.

3.4 The structure of director networks

An alternative perspective is to look at the number of board seats in the firms for each region. In doing so we can examine whether board positions are filled by a director who operates in one region, i.e. regionally fixed, or whether their activities cover other areas, i.e. regionally mobile. In Table 9.2 below, we see that there are a total of 1257 board positions filled by a director based only within the region, only 177 (12.3%) positions are filled by directors who have multiple geographical coverage.

Table 9.2 Regional director mobility

Region	Positions held by regional mobile directors	Positions held by regionally fixed directors	Total positions	%
East	82	587	669	12.3%
London	48	351	399	12.0%
Scot	30	193	223	13.5%
Yorks	17	126	143	11.9%
Total	177	1257	1434	12.3%

Chi-square test comparing proportions of mobile directors to null hypothesis of no difference from the proportion for the total is accepted (pval = 0.96)

Is there a difference in the activity level of directors in each single region compared to the multi-regional directors? A simple calculation suggests that on average each single region director accounts for 1.2 board seats, whereas directors with a multi regional profile on average have 3 board seats. However, in order to have a multi regional profile the director must have a minimum of 2 board positions. If we remove directors with only a single directorship, and then compare between regionally fixed and regionally mobile directors, we find little difference in their activity level. For example, directors who have multiple

affiliations but are active in only one location are found on 2.8 boards on average, compared to 3 boards for multi-regional directors.

A further point is that the proportion of board positions filled by directors who are regionally mobile is relatively stable across different regions. The number of individuals with expertise in directing firms across different locations is proportional to the number board seats available in a region, and ultimately the number of firms. There may be a variety of explanations for this observation, but it emphasises that regions must operate with the talent it has locally, rather than expect to be able to recruit the relevant experience from elsewhere. Only a proportion of firms will have access to expertise from these more mobile directors, in line with the number of funded opportunities in the region. The implication is that the more firms in a region, the greater number of mobile directors and the wider the geographical network of the region.

8.4 The structure of director networks

In previous research on directors Rosa and Scott (1999) showed a high proportion of high performing firms had multiple directorships, and Storey et al (1987) reported 75-80% of high growth firms had multiple directors. Our sample of firms has received venture finance, indicating that they have high growth expectations. We exclude all directors with affiliation to only one firm; instead we are interested in directors with ties to several biopharma companies.

In the sample of 108 firms used in this research, we find that 87% (94) of firms have shared a director with another firm in this sample. The cumulative approach taken to mapping the directors is not directly comparable with previous work and explains the higher proportion. It does agree with the overall findings that high technology firms are likely to involve a core of dedicated directors. Next we examine the core of network of actors that have a history of being a director on more than one firm.

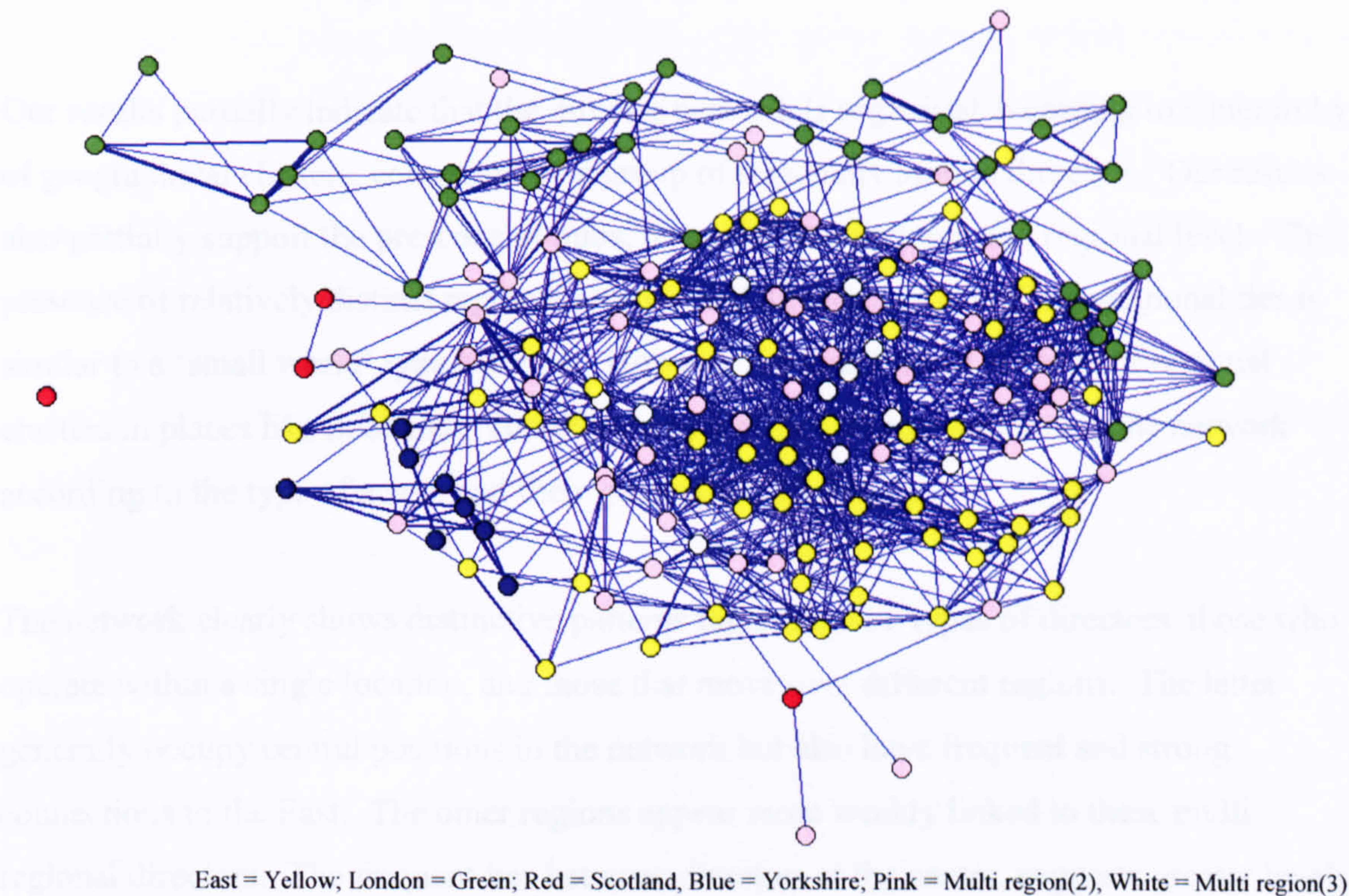
8.4.1 Multiple director relationships

Figure 9.3 shows the relationships between directors who have served on board of the same firm (within the sample of firms used). The network shows a total of 171 directors from the original 1052 directors we have in the database. We also code the directors according to their operational geography³¹ as represented by the colour of each node. The structure is achieved through running the Fruchterman Reingold and Kamada Kawai algorithms within the network software Pajek, until a stable structure is obtained. The

³¹ The number in brackets for multi-regional directors shows the number of regions they operate across.

structure is graphed with the aim of drawing equal length vertices, such that similarly connected vertices should be placed near to each other and should minimise crossing of vertices.

Figure 9.3 Sociogram of director network



A visual inspection of the network shows one main component, and one isolated vertex. As would be expected from using directors with multiple affiliations, the structure of the network is dense and formed of one main component. One investor is isolated, and tied to several firms without involving any of the other directors.

The coding of director's geographical location shows that director's positions in the network structure are grouped by their geography. In part this is a function of the coding scheme; a director only based in London is likely to sit on boards with other London based directors. However, the directors within each regional group occupy distinct positions in the network. For example, at the centre of the network the linkages are dense with frequent connections between a core group formed of directors who are from the East or operate across multiple locations. As we move to the outer edge of the main component we find London based directors form a connected group which has multiple ties to the core central group. London directors form a lower density group, formed from smaller sub-

clusters of repeated interactions shown by the thickness of the lines³². The directors based in Scotland and Yorkshire who feature in the network, are fewer in number and also attached to the outer part of the network. The Yorkshire directors are shown as a strongly interlocked group, with links to network centre through multi regional directors, whilst the Scottish directors are fragmented, with one director³³ isolated from the main component.

Our results partially indicate that the director network is organised according to a hierarchy of geographical clusters, connected by a group of regionally mobile directors. Our results also partially support the presence of hubs, operating at a national and regional level. The presence of relatively distinct regional clusters and directors creating inter-regional ties is similar to a 'small world' type network. However we also find an absence of regional clusters in places like Scotland. Therefore we identify different patterns in the network according to the type of actors and their geographical location.

The network clearly shows distinctive patterns regarding two types of directors, those who operate within a single location, and those that move over different regions. The latter generally occupy central positions in the network but also have frequent and strong connections to the East. The other regions appear more weakly linked to these multi-regional directors. The frequent ties between directors at the centre, suggests greater levels of social capital and a structure more similar to that we expected, where loose firm boundaries encourage the movement of people from one firm to another. These central actors are active in a well developed social network connected to all regions, suggesting information about opportunities and work practices in the UK will travel easily within the group. From a career development perspective these well connected directors have the greatest opportunity to learn from each other. Directors in regions such as London, Scotland and Yorkshire have more peripheral positions in the network and interact with a smaller number of directors, generally from the same region. Directors with peripheral positions in the network have more limited opportunity to work with different directors, and information and knowledge from around the UK may not be as easily accessible. Directors in peripheral parts of the network may lag more centrally positioned directors in their ability to develop the type of 'business scan' we discussed previously.

³² In networks with directed lines it is usual to talk about strong and weakly connected sub-groups. More frequent linkages between actors could be described as stronger, and we refer to this meaning when we talk about multiple relationships between directors. "One mode networks derived from two-mode affiliation networks are often rather dense. They contain many cliques, so we can analyze the structure of overlapping cliques or complete subnetworks if we want to detect cohesive subgroups", "Multiple lines are considered more important because they are less personal and more institutional". P.109 Wouter de Nooy et al (2005)

³³ John Pool is an executive director of several biotechnology and healthcare firms and an advisor to Scottish Enterprise.

8.5 In-demand director backgrounds

Focusing on a well connected sub-group of 59 directors with three or more links (degree>2) to firms in the sample, we find that 49% have an experience of being an investor, 25% are involved in acting as biotech advisors including legal advice and consulting and 22% are classed as professional directors with a history of directorships in biopharmaceutical and other sectors. Excluding investors, only 17% of this group of directors had involvement in founding businesses and could be described as bio-entrepreneurs. The largest group of specialists with multiple involvements in biotech businesses are investors. The presence of independent directors or serial entrepreneurs (not associated with an investment fund) was lower than that of investors.

Looking at our data on the qualifications of in-demand directors we find a high proportion (31%) of directors have a doctorate. Additionally, based on the available employment history, around 20% of directors had previous experience of working in the Pharmaceutical Industry. The breakdown of qualifications by the director classification is given below.

Table 9.3 Qualification level of highly connected directors

Directors (degree >2)	Accountancy	Legal	Doctorate	MBA	Total
Venture capitalists (or previous experience)	14%	0%	34%	0%	29
Consultants	0%	40%	13%	7%	15
Professional directors	0%	0%	46%	8%	13
Entrepreneurs	0%	0%	50%	0%	10
Others	0%	0%	25%	0%	4

This brief analysis indicates that key co-ordinators in the network are likely to have backgrounds in venture capital. The high level of doctorates and backgrounds in pharmaceuticals in the sample suggests that these in-demand directors will also have some relevant technical knowledge. Perhaps most interesting is the strong presence of legal advisors taking multiple board positions. This indicates that at even for early stage biopharmaceutical firms, guidance regarding legal issues is strongly demanded.

8.5.1 Strength of ties

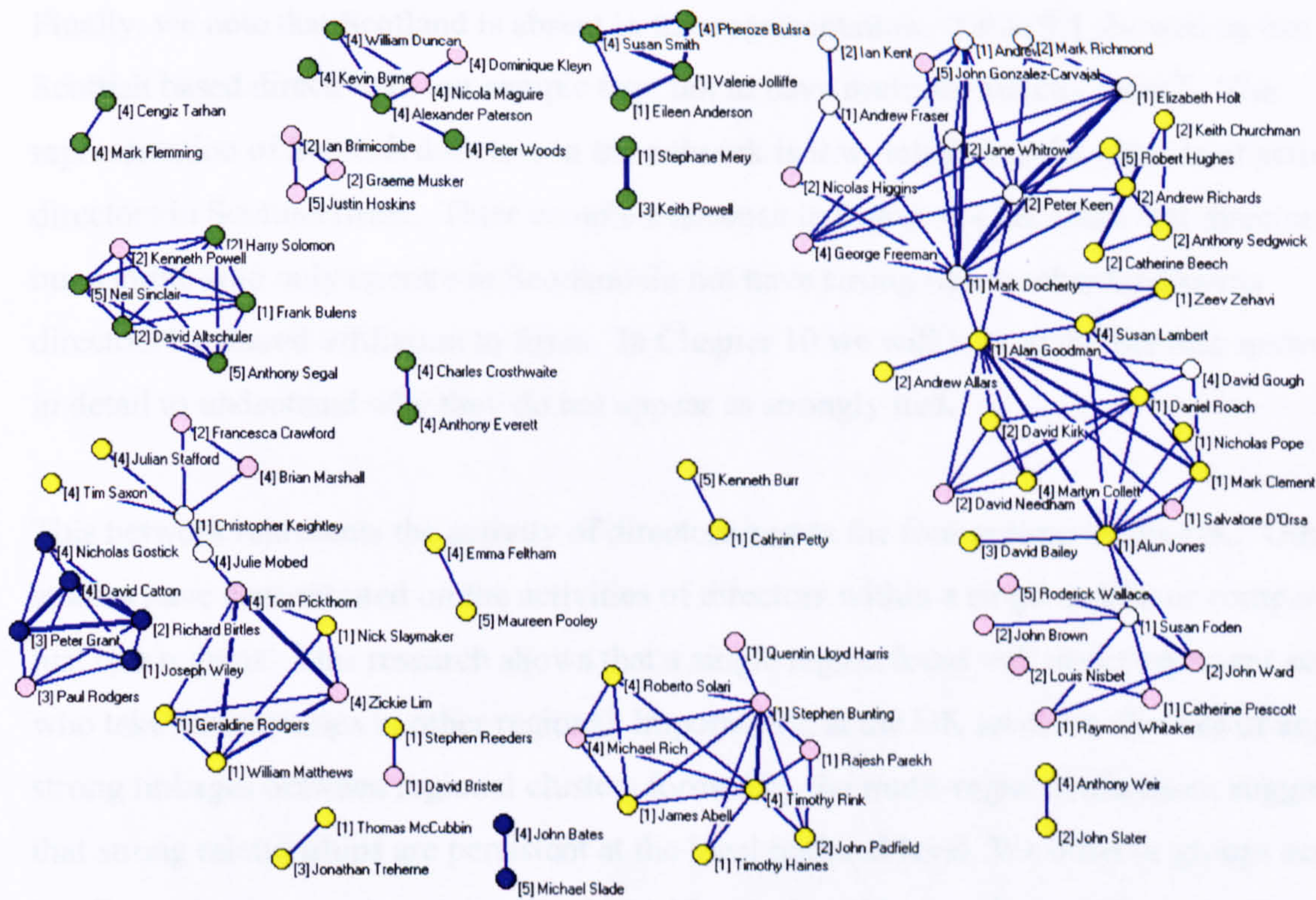
In Figure 9.3 we identified a core of directors with multiple interests which formed a well connected single group of directors, where regional patterns can be identified within the main component. This view of the network gives equal rating to relationships that may occur as a one-off, compared to distinctive repeated patterns of relationships.

To understand the distinctive core patterns of relationships we concentrate on repeat relationships within this core group. We remove links between directors that have

occurred only once (multiplicity = 1). We show directors who have had an involvement in the same firms more than once in Figure 9.4 below. Following our discussion in Chapter 7, repeat ties indicate a stronger connection between two individuals and can be associated with the development of trust between directors.

It is worth noting that our interpretation of the links between directors should be limited to dyadic ties, rather than longer paths between any two directors in a cluster. For example the firms that Susan Smith and Valerie Jolliffe have in common, may not be the same as the firms Eileen Anderson and Susan Smith have in common. Therefore, we cannot always interpret the mini-clusters as being based on exactly the same firms (although this is likely). However, these ties do indicate clusters of strong relationships in the network.

Figure 9.4 Sociogram of directors with line multiplicity >1



Colour codes as in Figure 9.3. Number codes: 1 = Venture capitalist, 2 = Professional director, 3 = Entrepreneur, 4 = Consultant/advisor, 5 = Unclassified

The colour coding in Figure 9.4 is the same as previously used. The figure shows the modified network is now highly fragmented with different clusters of directors. The thicker the line between directors, the more firms, or repeated affiliations they have in common. The values of the line range from 2 to 5 shared firms. The largest component or club (top right) includes directors based in the East and with no particular fixed location. In fact, a general feature of the larger components in Figure 9.4 is their strong attachment to a particular region, but with the addition of directors without a particularly fixed

location. If we look at the largest cluster in detail we can see that directors such as Alun Jones, Mark Docherty, and Peter Keen provide key links that form the cluster. In fact removing these directors would result in four smaller structures, two of which would include no locally tied directors. The first small network structure is centred on Susan Foden; the second is based around Peter Keen and Mark Docherty. We note these directors' names and will return to them in Chapter 10.

This discussion shows that groups of nationally active directors have strong ties to directors in the East. These strong ties are not found in other parts of the network. For example the London based directors are shown in several relatively small clusters, and directors in Yorkshire also formed in two groups. Only the larger of the London and Yorkshire clusters have any strong ties to more nationally operational directors.

Finally, we note that Scotland is absent in this representation. Table 9.1 showed us that Scottish based directors in our sample tend not to have multiple director roles³⁴. The representation of Scottish directors in the network is low, relative to the number of active directors in Scottish firms. Their complete absence in Figure 9.4 indicates that directors in our sample who only operate in Scotland do not have strong ties to other biopharma directors by shared affiliation to firms. In Chapter 10 we will look at the Scottish network in detail to understand why they do not appear as strongly tied.

This network represents the activity of directors across the four regions of the UK. Other studies have concentrated on the activities of directors within a single region or compared just two regions. This research shows that a single region focus will under represent actors who take directorships in other regions. Importantly, at the UK level the absence of any strong linkages between regional clusters formed by the multi-regional directors, suggests that strong relationships are persistent at the local regional level. We observe groups acting locally, and groups acting nationally, but without any evidence of repeated connections across different groups of locally embedded actors. This absence of strong relationships is in contrast to Figure 9.3 which included weaker relationships between directors. This matches our expectation that strong ties are generally facilitated by proximity between actors.

³⁴ They may of course be active in other sectors and different firms than in our venture backed sample.

In Figure 9.4 we also categorise directors according to their background, as shown by the numerical code. This means we can examine each cluster using information on the director career backgrounds. For example, we find that the large Eastern orientated cluster of directors, including Jones, Docherty and Keen includes all five types of career backgrounds.

When we analyse Figure 9.4 using information on the backgrounds of directors, we find an even distribution of career backgrounds across each cluster of directors. We find that each cluster contains directors with a variety of backgrounds. This indicates that directors within each cluster fulfil particular roles making distinctive competence based contributions to the boards they sit on, for example providing investment expertise, entrepreneurial experience or general 'business scan'. These directors are in-demand and choose to form strongly connected groups which provide a range of benefits to the firms they work with. We find a range of backgrounds are necessary to establish core clusters or 'clubs' of directors. In these clubs we expect that the reputation and performance of each individual maintains their access to the group. Given that our data includes only venture capital backed firms, our findings link well with the literature that suggest investors play a role in coordinating access to a range of resources and strategic advice.

We also find venture capitalists directors are distributed across different groupings, rather than being concentrated into one particular club. This indicates that investors have strong connections to directors with a range of experiences. However, we note each cluster is tied to specific locations, and some regions are only weakly represented. Thus we find little evidence that investors form strong connections with directors across several regions. Instead we find investors appear strongly tied to groups of directors in specific locations.

8.6 Conclusion

In this chapter we have researched the relationships between in demand directors of biopharmaceutical firms in four UK regions. We have assumed that active directors are in demand because of their expertise. We have found only a minority of directors who have experience in multiple biopharmaceutical venture capital backed start up firms. Of this in-demand set of directors we have divided them into two groups, those who operate within regions and those that operate across regions.

We have found directors who stay in one location, have a similar activity level to those that operate across regions. We have found that mobile directors are distributed proportionally

to the number of board positions in each region. As such, regions with a larger number of firms, such as the East, benefit from a larger population of directors with greater start-up experience whether these directors are geographical local or mobile.

The East is central for the network of directors, particularly for directors who also take positions on boards elsewhere. A consequence of regional concentration is that directors based in the Eastern region are strongly tied to each other, and also many of the mobile directors. The opportunity for directors in Cambridge and the surrounding areas to share knowledge and contacts with other experienced directors within the region and further away is greater than in the three other regions we have studied.

The network of weakly linked experienced directors includes directors from all regions. However we find that strong ties reflect director's regional preferences. The analysis broadly suggests directors prefer to remain in one location. We find support for the idea that social relationships decay with distance and that proximity facilitates strong ties between directors. This result implies that familiarity, trust and therefore social capital is organised at a regional level. Consequently we find directors in the East with experience of working with entrepreneurial firms are clustered into groups.

Directors in other regions, such as London, and particularly Scotland and Yorkshire, are peripheral to the network of directors, and have much weaker connections to the centre of the network. Although weak ties are associated with the flow of new information these regions lack directors with strong connections to other directors that operate across regions. This shows that access to resources, contacts and knowledge sharing with the centre of biopharma activity in the East, may be weak and infrequent. The literature on interlocks suggests these long distance ties are likely to be more formal targeted attempts to access resources in the East, rather than long term reciprocated relationships. Strong ties between investors reflect ties that occur between local actors and suggest a lack of intra-regional trust based exchanges. This observation reflects Gorton (1999) that actors in more isolated locations, may prefer to work in local markets, rather than attempt to integrate with other more attractive locations.

One particularly interesting observation that needs further investigation is the low presence of directors with multiple firm experiences who operate only in Scotland. The Scottish region has received a high level of investment, and previous chapters shown a highly

active investment environment. One explanation for the lower representation of directors of Scottish firms may be due to a lack of director specialisation in biopharma.

We must also note that we only represent one type of relationship, and therefore directors based in regions other than the East may compensate for their peripheral positions by engaging in a range of other types of informal networking activity that is not captured in this analysis. For example, directors of firms in London may have a range of sources to obtain advice given the large business population in the city.

In the thesis we have found persistent regional variation and concentration of investment activity. Our analysis of director networks supports this view of distinctive regional characteristics and concentration of networks with geography. In contrast, our analysis of the investor networks in Chapter 7 shows that the central actors have national reach, and invest across regions, whilst investors who remain local, link to the centre of the network, rather than with other local investors. However, we have yet to specify where these investors are located. It seems likely that despite being able to invest over distance, even national investors will locate in core investment regions.

In Chapters 7 and 9 we have analysed network activity according to different types of actor. In Chapter 5 and 6 we view networks as influencing both the supply and demand for investment. We have indicated that for an investment to occur, investors need to be in contact with entrepreneurs and vice versa, suggesting a wider network including different actors in the investment process. In the final chapter of this thesis we analyse the relationships of investors and directors together to help bring together the analysis in Chapter 7, 8 and 9.

9 Regions in focus

9.1 Introduction

The aim of this chapter is to consolidate our previous empirical work and sharpen our analysis of regional differences in network activity. In this chapter our goal is to examine the links between directors, investors and firms, using networks to facilitate our discussion. To support our analysis we also use additional material to understand the wider dynamics and regional influences present.

We also take this opportunity to think carefully about what we mean by ‘region’. In many ways our four regional cases, capture the extended activities of four UK agglomerations, clearly that of the City of London and surrounding boroughs, Cambridge and Norwich (East), York, Sheffield and Leeds (Yorkshire), and finally Edinburgh, Glasgow and Dundee (Scotland). The results from Chapter 6 also suggest these regions have a varied level of embedded venture capital activity, ranging from the strongest embedded activity in the East, to the weakest in Yorkshire. In this chapter, we will use these urban identities to help focus on the characteristics of the regions we have analysed.

9.2 Method

In this chapter we present four detailed case studies of UK biopharmaceutical regional activity, using relational data from Chapter 7 and 9, interviews, press reports and literature published on the internet to develop a detailed region analysis. We use sociograms to help to understand intraregional connections, using the full 2-mode representations to show the firms and connecting actors in detail. Consistent with previous chapters we concentrate the analysis on connecting actors in the network, focusing only those vertices which have two degrees or more. This ensures that the network map is drawn to show actors with more than one interest in the biopharmaceutical firms in a region. The network diagrams, grouped for each region, are shown in the appendices. In the networks we code investors according to their coverage of the UK, as in Chapter 7.

Our purpose is not to evaluate the size of the networks. We have shown in Chapter 9 that the number of active directors in a region is proportion to the number of firms. In this chapter we concentrate on the structure and detail of the network ties. It is also true that network statistics, such as density, become more difficult to compare across different network sizes. We have deliberately chosen four case study regions to illustrate the variation in regional activity, and we expect a large variance in the size and structure of regional networks. To help make sense of these networks, we also use additional

background information to help our analysis and profile the most active directors in each region. Tables and figures referred to in this chapter are included in the Appendix for Chapter 10 (section 13.4), with the exception of Figure 9.4 which is included in Chapter 9.

We also review the locations of VC offices investing in firms in these regions, to understand the type of investor operating in particular locations. In Table 13.7 we summarise the proximity of investors to each deal and type of investor according to their coverage of the UK (i.e. overall presence in the UK according to information on all deals). In the network sociograms we also include a numerical code to show where the investor is located, relative to the portfolio company. We make an assumption that the nearest investment office to the firm is the active office. The codes are explained in the appendix for this chapter.

We start our analysis with the Eastern region, and use this region as a reference to compare the other regions. We then continue with London, Scotland and finish with Yorkshire. In each case we provide a brief discussion of the regional history, its main cities, university research centres and any literature available to inform our discussion of the relationships between investors, directors and the firms they share affiliations with.

9.3 *The Eastern region*

Although the Cambridge region dominates the Eastern region in terms of research output and investment, the DTI (1999) report on Biotechnology Clusters in the UK notes the presence of internationally significant research centres in Cambridge and Norwich. However, the majority of biopharmaceutical firms in the dataset are based near to Cambridgeshire, with Cambridge University spin out firms at the core of the regional network.

Despite the prominence of Cambridge in our data, the economic development of Cambridge was restricted until the late 1960s (Massey et al, 1992). Prior to this period, Cambridge was renowned for its University and specialist research centres, such as the Medical Research Councils Laboratory of Molecular Biology built in 1962.

The commercial development of the City was restricted by strong planning regulations, such as the use of a 'green belt'. In fact companies looking to position large research centres in Cambridge, such as IBM were turned down (Massey et al, 1992). Eventually the combination of pressure from influential academics and a change of Government resulted

in a relaxation of restrictions to allow a 'science-based' development of Cambridge initially focused on computing. In 1972 Cambridge built its first science park (Massey et al, 1992).

In addition, other actors influenced the development of the region. One example was Cambridge Consultants Ltd (CCL), who focused on commercialising University research through the creation of spin-out ventures (Papaioannou, 2006). During the late 1980s the support of people involved in organisations such as CCL and local experienced entrepreneurs, helped to provide a supportive environment for new firms (Athreye, 2004). Cambridge University's research provided new innovations and material for further spin-out activity (Garnsey and Heffernan, 2005), increasing the demand for office and laboratory space from entrepreneurs. In response, additional business and science parks were created, such as the St John's Innovation Centre, and the number of small hi-tech firms proliferated (Druile and Garnsey, 2000).

Cambridge has become "one of the main centres of technology innovation in Europe" (Pesola, 2005a). A result has been the branding the region of hi-tech activity around Cambridge, as 'Silicon Fen', as a comparison to its much larger US counterpart, Silicon Valley (Pesola, 2005b). The region also boasts a bio-cluster in the region formed of approximately 200 biotechnology firms and 350 services providers (Papaioannou, 2006).

9.3.1 Cambridge and 'social networks'

A strong component of the reported success of the region is its reliance on social networking to promote entrepreneurial activity, (Pesola, 2005a), information sharing due to transfer of people between firms (Athreye, 2004) and ultimately an accumulation of social capital (Garnsey and Heffernan, 2005), where,

"social networks are in fact spin-out networks. This means that '... people who have left another company, they will still have ties with their former colleagues, they will still phone them up when they have a problem, there is this continual e-mailing and phoning going on between people asking for information, asking for various contacts'" (Interview excerpt from Papaioannou, 2006 p.11).

This is also supported by investors operating in the area, like 3i's Laurence Garrett, head of the Cambridge office who states that "wealthy investor networks have become more organised....and serial entrepreneurs, like Acorn's former chief executive Stan Boland, more common" (Daily Telegraph, 2006). Athreye (2004) also notes the importance of groups of individuals involving people like Stan Boland, with diverse career histories, as entrepreneurs, scientists and later venture capitalists. These small groups can be highly

influential in the formation of new biotech firms and the transfer of information between investors, universities and other local institutions. However, a reliance on very small groups may come at the risk of excluding outsiders from their networks (Athreye, 2004).

Thus, Cambridge is an example of Florida and Kenney (1988) technology type centre, with entrepreneurial activity concentrated around the city's University research supported by strong networking between local actors. Although the growth of the city may have been slowed by the type of infrastructure issues associated with UK cities, such as congestion and a lack of housing (Pesola, 2005b, Guthrie, 2007), 'greenfield' land has become available to build the infrastructure for the new technology businesses in areas around the city.

9.3.2 Eastern networks

The Eastern investor network is the largest regional network of the four regions we study. Although it is formed of 143 investors, it is not a single component network. For example we note several firms which have received 'one-off' type financing from internationally based investors. In fact international financing is a feature of many of the firms in the region, particularly those that have established themselves to point of acquisition, such as Kudos Pharmaceuticals, acquired by Astra Zeneca, or IPO, in the case of Intercytex.

As expected, the Eastern region has a range of investors. It includes a strong presence of professional VC's, public investment both directly from DTI and through University funds, finance from corporate venture capitalists and charity investment funds and other regional investment initiatives. The major private VC's are strongly linked, having invested in the same firms on numerous occasions. The DTI has frequent weak links to firms in the region, some of which are linked to private VC others to companies receiving other public or public/private funding.

In line with our discussion of Cambridge we find our Eastern region networks (Figures 13.2, 13.3 and 13.9) shown in the appendix, show well connected networks, with investors and directors who are highly connected. The distinction between the centre and the periphery of the network is less clear as highly connected directors and investors are spread through the network. Typical of a random type network structure, we find no obvious central actors and ties appear evenly distributed.

We also recall that the names of investors with connections to several biopharmaceutical firms in the region are familiar from Chapter 7, as central investors with a national presence. A large number of these connecting investors have offices in London. However, other key investors in the region, such as 3i, Avlar Bioventures and Abingworth have offices in Cambridge. Despite many investors with local offices we find relatively few investors with multiple ties who only operate in the region. This supports our view that investors in Cambridge also invest across the UK.

We also recall from Chapter 9 that repeated patterns of affiliations between groups of directors are a feature of Eastern region. For example, in Figure 13.10 we find the directors of Amura Holdings share the same connections to many other firms, such as CENES Pharmaceuticals, De Novo Pharmaceuticals and Cambridge Biotechnology.

9.3.2.1 Investor strategies

Our analysis of director and investor networks finds evidence for common links between the two network representations. We find that repeated ties between directors in the network often correspond to repeated ties between investment companies. We suggest that this may reflect distinctive investor strategies. We find an accumulation of directors with experience in the venture capital industry. Fourteen of the individuals who have served on the board of more than two firms in the region have backgrounds working in venture capital.

For example Alan Goodman and Daniel Roach are highly connected directors in the East, both are from the same investment company Avlar Bioventures, which is based in Cambridge. In fact Avlar was set-up by Goodman and Roach, following a successful partnership investing as business angels. Avlar has also invested in many of the same firms as Merlin, a London based investor. It follows that directors, such as Peter Keen, Mark Clement and Mark Doherty, who are individually well connected in the network, have been investors at Merlin, and are tied to the same firms as Goodman and Roach. It naturally follows that investors who syndicate, and finance the same deals, may both provide directors to the boards of these firms. Repeated ties between investment companies and respective investor directors represent strong bonds between investment companies, on a formal and informal level. It suggests that the strategy of these investors is to work very closely together, sharing information and supporting their investments.

Other investors have different strategies, for example Avlar and Merlin have also invested with 3i in several Eastern region firms. Here we also find strong ties between these

investment firms. However, we do not find such strong ties between the associated investor directors. In cases where 3i invests, we find the presence of experienced directors, such as Ian Kent or Susan Lambert on the board, in addition to the direct representation provided by other investors.

We also find some relationships between investors are not fully captured in our data. For example Avlar Bioventures, cite 3i, in addition to a number of large investment banks, as a direct source of funds for Avlar investments. This indicates a greater financial participation of 3i in supporting early stage firms. It also indicates a risk reduction or diversification strategy, whereby 3i invests in early stage firms through another investor's fund³⁵. It supports our observation regarding 3i's preference for using experienced industry based directors, rather than their own investors.

However, both strategies outlined suggest a concentration in relationships between particular groups of firms, investment companies and associated directors. Ultimately it means that these investors have a strong influence on the financing of Cambridge based firms. In fact, we suggest that relationships between investment firms and their representative directors are the explanation for the large cluster of strongly tied directors in featured in Figure 9.4. The largest cluster of directors in Figure 9.4 includes representatives of the main investors, 3i, Merlin and Avlar.

Other investors like Abingworth Management display a different operational pattern. Although Abingworth is connected to the Eastern investor network, it lacks strong ties with other investors through repeated relationships. Instead, we find a common group of firm directors involved in Abingworth's portfolio firms. We find strong connections between the group directors who share connections across the firms in the Abingworth portfolio, but much weaker relationships to directors associated with other funds.

Abingworth have strong ties to a relatively contained group of directors. This director group includes individuals like Stephen Bunting, who are investors at Abingworth. Other members of the group have mixed backgrounds, such as Timothy Rink who was an academic at Cambridge, then worked in the Pharmaceutical industry and was then a director of biotech firms. It follows that these directors appear as an identifiable group in Figure 9.4. The relational structure indicates Abingworth has a preferred group of

³⁵ We also find Merlin and 3i are backers of Cambridge University based funds, managed by Cambridge Enterprise.

directors, which are frequently found in its portfolio firms and not strongly tied to other investors. This type of strategy suggests a more independent investor, with a preference for dealing with trusted individuals with a range of backgrounds.

In contrast, we find University affiliated investors, such as Cambridge Enterprise capture aspects of these three types of private investor strategies. To some extent these university investors operate with a preferred group of directors. For example, Cambridge Enterprise's portfolio firms include a strong legal presence in the form of Zickie Lim and Tom Pickthorne, both lawyers at the same legal firm. Cambridge Enterprise also uses its own staff on the boards of firms it finances, such as the managers of the University's Challenge fund. It follows that we also find these directors appear as a group in Figure 9.4.

We also note that University associated investors, such as Cambridge Enterprise or CRIL (Cambridge Research and Innovation Ltd) lack strong ties to the private investors. It follows that whilst Cambridge Enterprise has links to Avlar Biosciences, having invested in the same companies, we only find weak links between Avlar's directors and those directors connected to Cambridge Enterprise. Alternatively Cambridge Enterprise funded firms also include directors like Christopher Lowe, who is director of the Cambridge Institute of Biotechnology and was non-executive director of 3i Bioscience Investment Trust fund. Lowe is connected to different firms across the network and therefore shared boards with a range of other directors.

9.3.2.2 Cambridge as a magnet

As Cambridge is clearly a focal region for UK biotechnology activity and investment, this raises the question of whether firms that move to the region, can access the network easily. The analysis of firms in the region highlights variety in origin, particularly where firms are not strongly connected to the network in terms of either shared directors or shared investors.

Firms that do not originate from the regional universities can be identified because they are only loosely connected to the network. For example CellFactors Plc and Cresset Biomolecular are attached to the network through a single shared director. CellFactors, a mostly self-funded firm, with one round of investment from a Cambridge based early stage fund, spun out from the University of Sheffield. It went into administration after being unable to raise additional finance in 2004 (Drugresearcher.com).

However, other firms without Cambridge origins are well networked, particularly those which can be traced to London's premier Universities. For example Amura Technologies, now part of Amura Holdings, has ties to Imperial College, whilst Ionix Pharmaceuticals co-founder is a Professor based at University College London. Both firms are tied to the Eastern networks, particularly to investors and associated investor directors in the region. The attraction of Cambridge also extends to spin outs with shared origins in Cambridge and other universities such as Sheffield, Manchester, Edinburgh and California. These partial parentage firms are also generally connected to the Eastern region network.

The connection between London and Cambridge is also shown in Table 13.7. The table shows that the Eastern region has a high representation of national investors, although a far lower proportion of investors have a local office. The East is actually relatively dependent on investors based in the surrounding regions, particularly London. We also find our data indicates that a high proportion of overseas investors are active in the Eastern region. As international investors are likely to be reliant on UK investors for information regarding investment and co-investment opportunities, the close connection of Cambridge to London may provide access to international finance.

9.3.2.3 Moving out, but remaining connected in.

A strong feature of the Cambridge cluster is its reliance on overseas markets (Athreya, 2004). It is not surprising that firms in the region need to expand their presence globally. An alternative strategy to gain access to overseas markets and finance is to move the firm abroad. This is a feature of some spin outs from UK institutions, one example is Domantis, a domain antibody company, which after spinning out from the MRC research had its R&D centre located in Cambridge, but located its corporate headquarters in the US. Domantis shares connections to other Eastern region firms through common investors, in particular 3i, and MVM and Albany Venture Managers but has accessed investors from overseas who do not feature in other firms in the region. Despite the relocation of the firm's headquarters we find that the directors of Domantis are connected to the Eastern network of directors.

9.3.3 Summary

As in the research by Myint et al (2005) and New (2003) we find a well established network of affiliations between directors and firms in the Eastern region. There is a heavy emphasis on Cambridge University as a spin-out source, boosted by the relocation of London based spin-outs. We find that the region has a core of specialist biopharmaceutical director expertise. The multiple relationships and the variation in strength of ties between

directors active in the East suggest the formation of social capital at the region level which helps to effectively distribute information, but also share knowledge and expertise across different groups of regional actors. In this respect our research strongly supports Garnsey and Heffernan (2005) view that social capital has contributed to the performance of Cambridge and surround region in supporting the development of entrepreneurial biopharmaceutical businesses.

It is clear that established venture capital investors have a history of operating in the Eastern region, such as Merin, Avlar and 3i. These investors operate closely together, whilst other investors such as Apax, Abingworth and local University Challenge Funds are active in the region, but clearly occupy different positions in the network by not investing in the same firms.

The Eastern region has a high concentration of active investors who link between different firms. However, in contrast to the local concentration of activity, investors are often nationally active. Although, some of the most active Eastern region investors have local offices, many are based in London. Therefore firms in the East are reliant on investors from London and overseas.

Repeat interactions between directors are often associated to director's ties to specific investment firms. We find many of the clubs of directors identified in Chapter 9 are connected to particular investors either operating in close syndicates, or alone. These strong relationships between groups of directors and investors should reduce information asymmetries between investors and firms and help avoid the difficulties that can arise when information flows between firm and investor are unbalanced.

In this respect we find the network has an advanced structure to support entrepreneurial firms. At a structural level the networks reflect random network properties facilitating the flow of information across the network. The network shows clusters formed of repeated links to support the development of trust, and an environment for sharing knowledge. These observations suggests a regional balance, where strong trust based ties improve the efficiency of communication and the transfer of knowledge for supporting entrepreneurial firms, yet the weak links help ensure that knowledge and information is spread across the region more generally.

Finally, considering the wider national implications of Cambridge, we find the presence of firms from other regions located in the East. However, firms moving to Cambridge without any ties to the University were not strongly linked to the director and investor networks. For firms without local ties it may be difficult to access the local expertise and gain access to local social networks and therefore benefit from the social capital resource. However, this was not shown for spin-outs from London's universities and matches our observation regarding the ties between London and Cambridge for finance. These connections between London and Cambridge may make relocation for London spin-outs easier.

9.4 *The London region*

9.4.1 Background

London has a long been associated with banking and finance serving as “the capital of the unregulated Euromarket” (Warf, 1995 p.61). Despite the growth of international finance over recent decades, accompanied with a reliance on high-tech global communications, London remains a meeting point for all the different forms of interactions in the financial services, as a centre for knowledge and financial innovation (Amin and Thrift, 1992).

Entrepreneurial firms in the region can be expected to benefit from access to international finance, proximity to the London Stock Exchange (LSE), and the associated accumulation business expertise and contacts that result from London the concentration of international financial activity. For example, Nature reported that Alternative Investment Market (AIM) of the LSE has attracted American biotech companies to the London market for their initial public offerings (Chipman, 2006, 2007), suggesting the availability of finance for these more specialised types of investment opportunity.

9.4.1.1 *London and the life sciences*

In addition to its presence in financial markets, London is also reported as having the highest concentration of “life-science research investment in Europe with 28 Universities, 55 hospitals and headquarters of many of the World's life-science companies” (Life Science Clusters, 2007 p.7). London is clearly an important centre of finance and technology, our research in Chapter 3 and 4 show that firms based in the capital region receives the large majority of venture capital finance, although only a small share goes to biopharmaceutical firms based in London.

However, Huggins (2006) suggests the concentration of research in the capital not been matched by commercialisation outputs, such as spin-out firms. The author suggest that a

lack of integration, communication and networking between the financial investment and higher education communities has held back spin out activity in London. Huggins (2006) notes that in contrast to the character of London as a global financial centre, University spin outs face difficulties in accessing early or seed stage finance, and experienced management to support the firms.

9.4.2 London networks

An inspection of the London network sociograms (13.4, 13.5 and 13.10) find that in line with the lower level of total investment received by biopharmaceutical firms in the region, the director and investor networks are smaller in size, due to a smaller population of firms.

As with the firms in Cambridge, the majority of firms in the London network originate from one of the city's universities. However, unlike Cambridge, London is home to multiple universities. In London, Imperial College (ICL), University College (UCL), and Kings College (KCL) are the main contributors of biopharmaceutical spin-off firms. These universities have internationally respected departments in fields relevant to biotechnology, according to the 1996 Research Assessment Exercise (Sainsbury, 1999). These institutions are also attached to technology transfer offices, such as Imperial Innovations or UCL Business.

In contrast to our analysis of the Eastern region, we find a relative absence of private venture capitalists in defining the structure of the network, particularly concerning strongly tied clusters. For example, the most connected directors in London are associated with university technology transfer offices and university affiliated investment funds.

We find directors operate in distinct areas of the network which are associated with spin outs from particular universities. For example, a large distinct "Imperial" group can be identified in Figure 13.11. This group is formed by connections between directors of firms spun out from Imperial. The Imperial cluster involves a large number of interconnected directors. At the centre of this group we find evidence of strong repeated ties. We can identify the core of the Imperial cluster in Figure 9.4, involving Paterson and Maguire.

Imperial Innovations, is a subsidiary company of Imperial College which floated on AIM in August 2006, with the aim of capitalizing on the Universities intellectual assets. Susan Searle, writing in Nature (2003) indicates that Imperial Innovations has been highly active in supporting Imperial's spin outs. Imperial Innovations provide support by being

proactive and hands-on, for example they may take board positions in the firm, or guide the firm towards specialist advisors. They can also help the firm obtain finance or recruit other professionals to support the firm's development.

It follows, given their hands on approach, that the directors involved in the Imperial group reflect connections through employment within Imperial Innovations, such as Susan Searle (CEO of Imperial Innovations) and, Robert Bahns and Naiem Hussain. Their hands on approach is one reason for their desire to invest directly in the Universities spin outs using funds from their IPO, to reap the full rewards of their efforts (Financial Times, 2006). Although this finance is evident in our data and networks, it became available towards the end of our observation period, minimising its impact in our analysis.

As with our discussion of Cambridge Enterprise, a similar type of technology transfer office, the two most connected agents in this Imperial cluster are both independent legal advisors (Paterson, Maguire). Both have experience in advising companies in corporate transactions. This matches with Imperial approach of providing external access to external advisors on tax and business issues at preferential rates (Nature, 2003).

9.4.2.1 London's investors

The London region has the highest proportion of investors with local offices relative to the other regions, as shown by Table 13.7. Around 39% of the active investors in London's biopharmaceutical firms are nationally orientated. We also find that the London network has a sizeable proportion of investors from overseas, as you would also expect given our discussion of London as an international financial capital.

In contrast, our analysis of the investor network and Table 13.7 emphasise a strong representation of investors who only invest in London, suggesting the presence of smaller sized investors in the region. Whilst large investors are active in London, they are not shown to be the most active investors in the London network.

One of the smaller investment funds used by many London biopharmaceutical firms, including those from Imperial, is the Bloomsbury Bioseed fund. This seed fund can invest in eight of the top London universities and research institutes in the life sciences. Stephane Mery as fund manager of the seed fund, has a high level of involvement in the London network, and integrates a range of different spin out sources. Stephane is frequently a director in the same firms as the funds entrepreneurial advisor, Keith Powell.

Another network cluster is attached to small embryonic firms, receiving small amounts of grant and venture capital finance from the Wellcome Trust and an investor called Javelin Ventures. Javelin manages several London University funds investing in technology from Universities such as KCL, where Susan Smith³⁶ has a role in managing spinouts. Jolliffe and Anderson are both managers Javelin, and additionally Anderson has other non-executive responsibilities which connect them to directorships of the same firms. We can identify Jolliffe, Smith and Anderson in Figure 9.4 as they form a strong mini-cluster.

Many of the firms from the Javelin, or Imperial group have not received finance from the large UK national investors (as at September 2006). Similarly, given the number of firms spun-out from Imperial, it is surprising that we find a low presence of repeated ties to venture capitalists in the Imperial cluster. Instead Imperial spin-outs are backed by a range of financiers, frequently with offices in the city. As our data is focused on the period prior to Imperial Innovations IPO, the absence of a consistent source of finance for Imperial firms may be one reason for Imperial deciding to provide their own investment funds.

The participation of the larger UK investors, who we are familiar with from Chapter 7, are connected to a small grouping of London biopharmaceutical firms. The grouping of large investors, both UK and internationally based, is strongest around companies such as Inpharmatica, Ark Therapeutics and Xytis Pharmaceuticals. These companies all share directors with Arrow Therapeutics. They are also relatively established firms compared to the Imperial and Javelin group and account for over half the investment (by value) made into biopharmaceutical firms in our London sample. Several have produced an exit for their investors, for example Inpharmatica was acquired by Galapagos, a European integrated pharmaceutical company, for €12.5m³⁷ in 2006 a relatively low return on investment. On the other hand Arrow Therapeutics was purchased by Astra Zeneca, for \$150m in 2007, clearing the £49m³⁸ of investment recording in the Library House dataset.

We can also link these firms to University College London (UCL) research. For example Kenneth Powell, who was head of the Wolfson Institute for Biomedical Research at UCL, acted as a co-founder (Arrow, Inpharmetica, Ark³⁹) of these firms and a CEO of Arrow.

³⁶ Based on limited information for Susan Smith

³⁷ <http://www.glp.com/press/2006/26.pdf>

³⁸ This is £4m higher than cited at <http://www.arrowt.co.uk/invmedia-current.htm>, but does not includes £4m GE Finance

³⁹ According to www.arrowt.co.uk. However no formal record as a director at Ark Therapeutics. We note that Arrow Therapeutics was founded by six scientists, from London, Newcastle, Cambridge and Oxford, and

Powell also features in the top science entrepreneurs list published in *The Times Higher* (2006).

A strong characteristic of the UCL group of firms is that they have attracted significant capital from the familiar names of venture capitalists operating in the UK such as 3i, and Merlin, Advent International and Advent Venture Partners and overseas investors. They also share six common directors, representing a range of backgrounds, particularly directors working for the venture capital investors, but also academic research and directors specialising in hi-tech firm development. The cluster of directors associated to these firms can be identified in Figure 9.4, involving Powell.

9.4.3 Summary

The London network, like that of Cambridge, is centred on spin out companies from academic research. Unlike Cambridge, London has several prominent Universities which create distinct patterns of director ties in the network. In particular we identified groups connected to Imperial and UCL. Universities in London have taken different strategies towards commercialisation, and created relationships to particular groups of directors to help manage their spin out business. It shows a varying degree of success in overcoming the integration of academia and business identified by Huggins (2006) for individual Universities.

We also find some evidence that structural patterns in the network of directors are tied to specific investors. We find a clear distinction in the network between different types of funding sources if we look at deals as opposed to the value of deals. The majority of firms in the network are reliant on range of financial sources, particularly local seed funds connected to universities, investment from the DTI and charities such as the Wellcome Trust. However, significant investment is concentrated into a minority of firms, receiving finance from predominantly private investors in the UK and overseas. Although these well funded firms are connected to UCL, with the exception of Kenneth Powell, the firm's director show less attachment to the University, acting as representatives of international investors or as professional directors.

From a regional perspective we observe weak integration of experienced management and investors working together compared to Cambridge. The failure to form strong associations between different groups is likely to restrict the development of social

moved to London following the first round of finance (www.arrowt.co.uk), suggesting a wider participation of University outside London in the creation of the firm.

networks and social capital which can be used to support biopharmaceutical firms. For example, there appears to be a low mobility of individuals between the university groupings. Our analysis of the network suggest resource (both financial and human) are effectively owned by University commercialisation clusters, rather than supporting development across all London Universities.

We previously commented that London and the East are tied. One issue for London is that firms which develop ties to large investors or non-university affiliated directors may relocate to Cambridge, particularly given concerns regarding office space and costs of working in the capital. As many of the firms we analyse are at a very early stage this may account for uneven distribution of investment in the network. Similarly, the weak links between local directors and large private investors may continue to encourage firms to relocate, despite the proximity to local investors.

9.5 *The Scotland region*

9.5.1 Background

Historically Scotland is a region characterised by declining output in heavy industry such as Shipbuilding (Papaioannou, 2006), competing on low cost, low skilled labour (Leibovitz, 2003) and a lack of entrepreneurial activity around new technologies (Papaioannou, 2006). Until the 1990s, Scotland suffered a number of ‘false starts’ in trying to stimulate the local economy. This included attempts by the UK Governments in the 1970s to push new industries, substantial cash and development agencies into the region to promote hi-tech industries. However, these strategies failed to establish Scottish owned enterprise and the associated cohorts of local influential entrepreneurs and investors (Papaioannou, 2006).

In the late 1990s, led by the RDA – Scottish Enterprise and the Scottish Executive, the economic development policy for Scotland was centred on tapping into local innovation and knowledge to drive the economy. A key part of which was based on developing bioscience clusters (Leibovitz, 2004; Rosiello and Orsenigo, 2008). The subsequent development in Scotland embodies a strong public “top-down” Government type approach (Papaioannou, 2006), which has consequences for the type of development compared to Cambridge. For example Scotland involves a wide range of public-private collaborations, between universities, firms and intermediary organisations. One such organisation is the Intermediary Technology Institute (ITI) designed by the Scottish Executive to broker public-private collaborations with commercial potential. However many of these collaborations are of a formal nature (Papaioannou, 2006).

In contrast, informal social networking between firms is found to be weak. This is partly because of fragmentation in the nature of SME activities and a desire to collaborate internationally. It is also because networking events often facilitated by public agencies are conceived to be geared towards promotion of high tech hubs, rather than the building social networks to support social capital as a factor in innovation (Leibovitz, 2004).

One advantage of a top down approach to regional development is a common alignment in the direction of development between different institutions, with initiatives geared towards issues of public interest. On a formal level the regional system of innovation is more cohesive, with participation from a range of public and private bodies (Papaioannou, 2006). Yet, consistently in the literature we find Scotland referred to as lacking critical mass in terms of cluster size and embryonic (Leibovitz, 2004) or lacking depth in terms of extensive networks between local firms based on information sharing for competitive advantage (Papaioannou, 2006). A particular issue with the embryonic nature of Scottish innovation system is a lack of experienced managers (Leibovitz, 2004) which has been slow to attract management from elsewhere, such as overseas (Rosiello, 2005).

9.5.1.1 *A region of the future?*

The situation in Scotland is changing, our analysis of investment in biopharmaceutical firms shows Scotland is one of the most important investment areas. The region has also received several high profile foreign investments in the area, with plans to extend bioscience activities. Leibovitz (2004) reports that Scotland has access to financial capital from sources locally and in London. In addition formal investment in biotechnology firms has been boosted by informal finance from a range of angel investors⁴⁰. The provision of investment has been further encouraged through the use of public-private initiatives, such as Scottish Enterprises co-investment scheme, where private investment is matched by the public purse. This maybe one explanation for the observation that in Scotland's bioclusters,

“one form of local social relations contributing to the viability of firms materialises in the form of investors and venture capitalists who serve constructively on the managing board of newly formed firms and provide advice and expertise on business strategy. There is some evidence that this is happening, especially in spin-out companies who have reflected positively on the role of venture capitalists in providing valuable advice and experience” Leibovitz (2004, p.1151).

9.5.2 Scottish Networks

One consistent observation with Scotland is the strength of the University science base. Bioscience activity is concentrated around Edinburgh, Glasgow and Dundee, each of

⁴⁰ Interview with Scottish angel investor/academic

which has recognised excellence in bioscience research, and contributes strongly to the number of UK science PhD produced each year (Life science Clusters 2007). In our database of firms, over half those citing locations in Scotland are from the regions' universities. However, the origins of the firms do not define the networks shown in Figure 13.6, 13.7 and 13.11, either in terms of shared directors or investors.

We find spin outs from universities such as Edinburgh, (Ingenza, Amoebics, and Ardana - from MRC lab in Edinburgh) or Glasgow (Grannus Biosciences, Crusade Laboratories) are distributed across the networks, and rarely share the same directors or investors. It follows that there are few strong links shown in either the investor or director networks. The only example of repeat patterns of affiliations between directors and investors is between Holt and Keen. These directors have connections to Merlin Bioscience, and the firms in question received finance from Merlin. In the investor network we find a strong division between the active connecting investors, in terms of public and private sources. For example 3i, Merlin, Scottish Equity Partners, share connections to a similar group of firms, whilst the remaining firms in the network are centred on more public based sources, such as, Scottish Enterprise, DTI, or University Challenge funds such as the Edinburgh Technology fund. However, we note that including all financing sources in the network representation, indicates a large number of investors, albeit not repeatedly investing within the sample of Scottish firms.

In agreement with the literature on Scotland, we find investment is attracted to specific opportunities, rather than being particularly reliant on a small core of specific investors, or investors attached to university sources. The network identifies a range of investment sources, from local to national or international funds, with offices in the region, adjacent regions, or located in the south. Table 13.7 shows Scotland has a high proportion of investors who only feature in the database as active in Scotland (54%); at odds with this, is the lower reported level of investors with proximate offices. This result is explained by the many 'un-coded' investors in Scotland. 'Un-coded' investors tend to be business angels or other informal sources where an office location could not be obtained.

However, despite the perception of adequate funding, like in Cambridge, some of the region's top performing firms have opted to move their commercial head office to the US. One example, Cyclacel, received \$9mill from Scottish Enterprise. However, it later underwent a reverse merger with a firm listed on Nasdaq, citing the need to gain access to the deeper pockets of the American investors (Pollack, 2006). Cyclacel is a

biopharmaceutical firm focused on drugs to inhibit uncontrolled cell division connected to cancer and other abnormal cell proliferation diseases. It has retained its R&D facility in Scotland which is guaranteed until 2010 under the agreement between Scottish Enterprise and Cyclacel, and has connections to Dundee and Cambridge.

9.5.2.1 Weak networks

We find weak regional networks between investors and directors in Scottish biopharmaceutical firms. Instead the region has an extensive pool of investors who have provided funds to Scottish biopharmaceutical firms. In fact the number of investors active in Scotland, per biopharmaceutical firm, is greater than found in the Eastern network. We find a wide range of investors, from business angels, to banks to public organisations are active in the regions firms. In further contrast, the strongest representation from large venture capital firms comes from Merlin, which has offices in London.

Investors in Cyclacel are typical of commitment we tend to find in Scottish firms. It includes investment from the main UK financiers of biotech, such as Merlin Biosciences, large investment banks such as Dresdner Kleinwort Benson, Lloyds and Citiventure, as well as individual private investors and their own associated funds, such as Brian Souter (founder and chief executive of Stagecoach) and their associated private investment fund, Highland & Universal Securities⁴¹ (Batt, 2003), in addition to public based funds such as Scottish Enterprise.

Few directors of Scottish biotech firms have multiple directorships. In contrast to directors in the East and London, the Scottish directors are also more difficult to code. Firstly because most directors appear have varied experiences, as entrepreneurs, firm founders and investors, and secondly because those who are non-executives are often not specialists in biotech firms and may have positions on non-biopharmaceutical boards.

We also find that many of the directors creating links between firms are more closely associated with the Eastern region, supporting our observations in Chapter 9 that directors with experience of biopharmaceutical firms on several boards of Scottish firms, are often multi-regional, rather than tied to Scotland. For example, individuals like Ian Kent who have committed their own investment to Scottish businesses, are familiar from the Eastern region networks.

⁴¹ <http://www.telegraph.co.uk/money/main.jhtml?xml=/money/2003/02/01/cncoach01.xml>

9.5.3 Summary

The findings from our analysis can be interpreted in view of the literature on Scotland we discussed earlier. The network analysis shows Scottish director and investor networks to be relatively weakly connected, but not necessarily as a result of an inability to attract management or finance to the area. Instead we see the reverse, that Scotland has attracted a diverse range of actors to the regions firms. However, like previous researchers have found, the issue is that the critical mass of interactions has yet to be reached, and resources within the region for biopharmaceutical firms are relatively unspecialised or shared with other regions. In time this may serve as an advantage for the region, our analysis suggests Scotland has developed a variety of links with local, national and international players, which may provide a fruitful foundation for the future development of the region. Given the reported strength of the research base, initiatives to attract further FDI for the development of hi-tech infrastructure and an ability to attract investment and expertise, the commercial bioscience presence in Scotland is likely to increase.

9.6 *The Yorkshire region*

9.6.1 Background

Yorkshire Forward, Yorkshire region's development agency, suggests that the region's clusters supported by the strength of the universities in the region, are some of the fastest growing in the UK. They identify their clusters according to seven technology areas with future potential, of which two are bioscience and healthcare (Yorkshire Forward). The DTI⁴² (2001) report on UK clusters finds that traditional activities in the region, such as the manufacturing of steel or textiles (wool), although past maturity, remain a feature of the region. The DTI report cites a number of industry clusters with expected growth potential in the region, including surgical equipment and web design. In cities in Yorkshire such as Leeds, financial and business service activity has grown by 50% in the last decade, with the presence of major national and international banks in the region (Willman, 2008, FT).

9.6.1.1 *Bioscience clusters*

Perhaps the most embryonic region of those discussed in this chapter is Yorkshire and the Humber. The 1999 Sainsbury report describes the Yorkshire region as at the start of developing a biotechnology cluster, with less than 30 firms operating in the bioscience area. This corresponds with our analysis that finds the Yorkshire region has the smallest number of early stage biopharmaceutical firms of the four regions studied, with only 13 firms included, three of which have no common directors. The Yorkshire region is a relative

⁴² <http://www.berr.gov.uk/files/file25035.pdf>

new comer to entrepreneurial biopharmaceutical SME and only two of the firms featured have any director history prior to 2000.

9.6.2 Yorkshire networks

It follows, given the regions embryonic status, that the regional network representations are small owing to a smaller population of biopharmaceutical firms. Like in Scotland, when we look at the most connected directors operating within the regions group of firms, we find a variety of backgrounds, with entrepreneurs, consultants, and professional directors.

Unlike Scotland, we find several individuals with many connections to the regions firms. There are signs of patterns of relationships forming. For example a group of firms associated with Sheffield University Enterprise and particularly Richard Birtles and David Catton are associated to the Biofusion fund.

The Biofusion fund has exclusive rights to the intellectual property resulting from the university's medical sciences (Times Higher, 2006). The fund was created by floating a company on AIM with 10 year rights to the University intellectual property (IP). The flotation raised £8.2m, and also attracted investment from the investment arm of Japanese Bank, Nikko Cordial Corporation. Nikko invested £2m in Biofusion and £10m in separate a University based fund (Barkas, 2006). Since 2007, Biofusion has grown to include the management of IP originating from Cardiff University.

The Biofusion fund is clearly active in financing Sheffield University spin-outs. Like Imperial in London, Sheffield University spin outs share the same directors. This group connected by Birtles and Catton, who are directors of Biofusion, are also shown as a strongly connected cluster in Figure 9.4. This group also includes several other experienced Sheffield based directors with experience as biotech entrepreneurs, pharmaceutical executives, such as Peter Grant and Paul Rodgers.

Leeds University spin-outs appear well connected with ties to the region's most active investors, they also share few common directors to firms in the region. For example, Photopharmica and Synoptix are isolated from the network and share no common directors with other firms in the region. Spin-outs from York University on the other hand, such as Cizzle Biotechnology, Pro-cure Therapeutics and Xceleron, form a small group sharing directors, but no coherent source of finance.

We notice that a number of directors cite historical connections to Cambridge, for example David Catton connects himself to Cambridge Consultants, and John Bates runs a consultancy with an office in Cambridge. However, the only director with multiple ties to Yorkshire firms and those in the East is Tom Pickthorne, a solicitor active in Cambridge. We also find Zickie Lim, listed as a director of Cizzle Biotechnology, who is tied to the same practice as Pickthorne. This indicates a tie between Yorkshire based firms and some of the supporting actors in Cambridge.

9.6.2.1 Regional funding

Another important aspect of the Yorkshire group of firms, directors and investors, is the tie to the White Rose Seed Fund, managed by Aberdeen Asset Managers, with Joseph Wiley as manager of the seed fund. This seed fund has invested in many of the firms connected to Biofusion. The White Rose Seed Corn fund is a £9m fund supported by Yorkshire Forward, Leeds, Sheffield and York Universities, aiming to invest in new technology emerging from the region. This fund, like the Bloomsbury fund in London, has invested across the region's University spinouts. It is one of the only actors in the region to invest across Universities; the other is the Wellcome Trust.

The full investor network in Figure 13.8 shows a range of active investors in the region, including private and public investors from Cambridge, additional public investment from the regions university based funds, the DTI and other private investors from predominantly London. However, of these only Biofusion, the Wellcome Trust and the IP group have funded more than one firm in the region. The IP group, like Imperial Innovations and Biofusion, is also floated on AIM, but is responsible for the commercialisation of a national network of university partners, including York and Leeds University.

One interesting observation in the Yorkshire region is that public finance has come from the RDA, various regional venture capital funds or the regional universities directly. For example, the direct DTI investment which is active in the other regions does not have a strong presence in Yorkshire. We find funds run by the regions universities and technology transfer offices, as well as investors like Ridings Early Growth Investment, and YFM (Yorkshire Fund Managers) which manage public private funds for Yorkshire, play small roles in supporting regional biopharmaceutical firms. The RVCF manager, YFM is a national investor as it manages several other funds including other RVCF in London and the South West. In fact we find RVCF are not a strong feature in any of the regional biopharmaceutical networks.

Overall, Table 13.7 shows that investors in Yorkshire region have a local presence (41%), but that the funds are managed by predominantly national investors (62%). We find that the region has the lowest level of investors, compared to London, East and Scotland, who only operate locally. However, this may overstate the role of national investors, as several national fund managers are responsible for allocating regional linked funds. The use of locally officed, nationally active investors to manage regional funds may have advantages. For example, such investors are likely to be experienced and have access to contacts outside the region. One element lacking in Yorkshire, compared to other regions is the presence of overseas investors. This may be a result of overseas investment into University funds, as in the case of Biofusion, rather than a particular absence of overseas investment.

9.6.3 Summary

Although, several Yorkshire firms have exited for their investors and returned a profit, such as Syntopix which floated on AIM, we find Yorkshire to be embryonic, and connections between different actors are only just beginning to form. We find Yorkshire is similar to Scotland, in terms of the mixed backgrounds of active directors, but also having ties to Cambridge based investors and directors.

We also find similarity to London with the prominent role of University based funds, particularly comparing Biofusion to Imperial, as both have raised finance from the stock market to support associated university spin outs, and assembled a group of directors to support the University's spin-outs.

9.7 Conclusion

This chapter has shown variation between regions according to the size and structure of networks. We have shown that regions differ according to the composition of actors, including investors, directors and research institutions. We have highlighted different relationships between networked actors can be explained by different strategies taken towards supporting entrepreneurial firms.

We observe Cambridge, compared to other regions, is relatively rich in experienced management, access to investors taking up board positions and providing finance, and able to draw in resources from London and further afield. Simultaneously we also find a role for the Eastern region in providing support to other UK regions, confirming that it acts as a centre for biopharmaceutical activity in the UK helping to transfer knowledge and expertise to other locations.

We find a regional perspective highlights the role of Universities in London and Yorkshire in terms of co-ordinating the investment and managing the development of the firms. In Yorkshire, Sheffield University has bundled its life sciences IP raising finance through its own investment/commercialisation arm, Biofusion providing a common source of finance and director support for Sheffield University firms. In London, Imperial was shown to be active through its commercialisation arm, Imperial Innovations. Imperial Innovations supplies management and finance to Imperial spin outs. In London and to some extent Yorkshire, University activity has also been supported with regional level public investment initiatives, managed privately has helped to link the different University activities.

However, our case studies reflect a distinctive or individualistic strategy used by some UK Universities. By bundling their intellectual property rights, UK Universities have been able to raise their own finances, through public stock markets, or private investors, hedge funds such as Sloane Robinson who provided finance to help commercialise IP from Oxford's Institute of Biomedical Engineering (Schurr and Boone, 2006). In some cases this is associated with a distinctive group of advisors and directors who work with University firms. It is beyond the scope of this thesis to examine the drivers and implications of this strategy in the long term. From a regional perspective, supported by our network analysis, it may work against policy designed to support regional level approaches to innovation and commercialisation. For example, whilst Yorkshire network of directors appears more connected than Scotland's, its investment performance is much poorer.

Scotland's regional approach appears different. In Scotland we find the full range of investment sources and directors with varied backgrounds. From our network analysis, relationships between the different actors appear more fragmented than we might expect given the level investment of activity. In Scotland the 'net' is thrown wider, repeated relationships between directors or investors are less frequent, but are more varied. We find links in the network to a variety of local actors, as well as those operating on a national or international basis.

In agreement with our discussion of the national networks, across the different regions, national VC investors are the main network co-ordinators, and each region has examples of investors with proximate offices, but who are also willing to invest nationally. This is also

true of investors based in London; we only find small investors connected to London's Universities operating regionally. Many of the major investors based in London are attracted opportunities outside the region, particularly to the Eastern region.

We find that our analysis supports the assessment of relationships between directors as being predominantly coordinated on a regional basis. We have explained the core groups of directors shown in Chapter 9, and related them to relationships between investors and research institutions. The analysis of the East emphasises the presence of venture capitalists in helping to facilitate interactions between different firms and directors, in London and Yorkshire the networks emphasise connections to research institutions. In London the co-ordination of the network is left to regional funds, whilst larger investors hand-pick their investments.

In recent years the DTI has favoured the creation of RVCF, which are privately run small funds. In the words of the directors of YFM, the funds have been designed to target opportunities not accessible for other funds (McFall, 2004). However with respect to RVCF managers interviewed in this research, the demands of high risk biopharma investment appear to be incompatible with the RVCF initiative, instead regional funding is provided through wholly public funds, such as University Challenge funds or universities own funds, sourced in a variety of ways.

10 Conclusion

10.1 Introduction

In this final chapter of the thesis, we return to the questions which we asked in the Introduction. These questions have defined the structure of our analysis. Our main aim in this concluding chapter is to bring together the findings we have generated from our previous chapters. In this final chapter we ‘sum up’ and address our original research questions. A secondary aim of this chapter is to assess the state of UK venture capital. We particularly focus on how our findings can contribute to policy for the development of the UK venture capital industry. We also consider the implications of UK venture capital policy for hi-tech sectors such as biotechnology.

An important contribution of this thesis is to provide an analysis of patterns of UK investment activity and their relationship to regional economic activities. The thesis also captures and describes patterns of interactions between actors involved in the venture capital investment process. The unique approach of this thesis provides a comprehensive assessment of UK venture capital activity at the national, regional and sub-regional level. Unlike existing studies of venture capital this thesis uses multi-level analyses to investigate the distribution of investment. In this way, the thesis captures the complexities of the organisation of UK venture capital, using regional statistics as well as a detailed analysis of activities. Our detailed analysis provides an important contribution to the literature. Firstly, we analyse the relationships between UK venture capitalists and a wider group of associated entrepreneurial actors and relate this to investment patterns. Secondly, interactions between actors involved in financing entrepreneurial firms are central to regional innovation system theory, but are not described in detail in the literature. Our analysis considers the role of different investor characteristics and their influence on the organisation of UK venture capital activity. We have also framed our analysis to reflect the current orthodoxy in academic studies, that policy initiatives should be based on regional or localised activities. Our final contribution in this chapter is to consider the fit of the region as a focus of policy activity.

The thesis combines an econometric analysis of UK regional investment with a social network analysis of regional and sub-regional relational activities. As a result, a key contribution of this thesis is to demonstrate the complexities in modelling the distribution of venture capital. Overall investment activity in the UK is concentrated in particular locations. However, the system supporting investment activity, such as the efficient

transfer of information and knowledge of opportunities, and the management of risk, operate on a national and regional level. Our research shows that investors operate across geographies, even when based in prime investment locations. However, the distinctive characteristics of UK regions are important. These characteristics include regional histories, proximity to London, the strength of relationships between actors in the local network, and their interaction with national networks. Thus, UK venture capital activity can be viewed as regional, but not in isolation from national and international systems. We find distinctive regional systems exist and create potential advantages, but also rely on interactions with investors and firm directors based in other locations within the UK and beyond. In this way, the thesis shows the importance of situating regional activity within a national context. The thesis also demonstrates the weakness of policies which fail to take account of the interregional interactions.

10.2 Answering the questions

In our thesis introduction we proposed two main research questions. Firstly, we were concerned with factors that determine the distribution of venture capital investment across regions in the UK. Related to this question we also seek to understand whether these relationships varied between biopharmaceutical investment and other sectors? In our second question we set out to describe how relationships between investors, firms and entrepreneurial firm directors are organised. An important link between literature on regional innovation, clustering and venture capital is the role of social networks. Thus, in line with the regional theme of the thesis, we specifically want to know how relationships between these actors are related to regional advantage, in terms of access to venture capital investment.

10.2.1 Regional variations

To answer our first question, we used the literature, predominantly from the US, to design a model based on the relationship between regional resources and venture capital. In the thesis we find the organisation of venture capital is regionally concentrated. We also find the concentration of investment is regionally embedded and the geography of investment is relatively fixed. In Chapters 5 and 6 we found that long-term regional characteristics had a strong influence on the investment activity regions. We found a significant part of the investment performance of key regions was due to regional specific factors, or regional endowments.

Our findings confirm Florida and Kenney (1998) and Martin et al (2005) research demonstrating the existence of persistent winner regions in terms of their regional share of

venture capital activity. However, we also extend our understanding of the organisation of venture capital in two important ways. Firstly, we demonstrate the persistence of regional funding variations is a result of long term factors, rather than changes in regional structural economics. Our research shows why policy attempts to manipulate the overall regional organisation of venture capital are difficult to apply successfully. Secondly, in Chapter 8 we found the same high performing regions were associated with higher levels of investor participation, even after controlling for other factors, such as investment risk and variations in the character and type of investors. Our research shows that the success of regions is related to 'labels' that indicate quality. Even after controlling for the structure of networks, we find key regions attract more investors, indicating that the quality of information and knowledge available in these areas is high. This finding is important as it demonstrates that investor characteristics alone are not enough to explain the strong performance of certain regions. Our findings indicate both the structure of networks, and the quality of information flowing around networks, are important in determining regional advantages.

Our research also indicates that regions should be analysed on a case by case basis. In Chapters 5 we demonstrate strong regional variation in terms of the heterogeneity of the relationship between venture capital and regional resources. We find the relationship of factors like human and technological capital, financial services, and entrepreneurship with venture capital investment, are not necessarily stable across locations. Interrogating regional activity further, Chapter 10 revealed important characteristics of the regions studied. For example, regions are made from cities that have very different histories in terms of their financial and industrial development. Similarly, even within the top UK destinations for investment activity, our research finds variation in terms of contribution of public investment and the influence of local or national government policy. Although we find universities are prominent innovation sources across regions, the wider role of the university as an actor in the development of firms varies from region to region.

However, our findings also show that biotechnology is different. In contrast to the overall venture capital industry, biopharmaceutical investment activity is not closely tied to unobserved long term influences, despite being concentrated into specific locations. Instead, we find the influence of regional resources on biopharmaceutical investment is more pronounced, particularly in terms of deal activity. Our results suggest that policy can influence activity in particular sectors.

In biopharmaceutical investment we conclude that deal activity has dissociated from long term background influences and is more closely linked to contemporary regional resources. This finding suggests a shift in the pattern of investment concentration, reflecting a more rational regional approach. However, we notice that our results vary according to whether we model the number of deals or the value of deals in a region. Compared to the flow of deals, the value of regional investment is explained more strongly by specific long term regional factors. A likely explanation is that policy, which has generally been directed towards local seed finance or ‘pump priming’, has increased deal activity in areas traditionally weak in venture capital activity. This has reduced some of the regional imbalance which arises because of long term factors. However, the substantial volume of investment required in sectors like biopharmaceuticals, has still remained more strongly tied to specific regions, reflecting a superficial policy influence. Thus we conclude that policy aimed at specific sectors must also be sensitive to regional activity. Policy must promote high quality opportunities to attract private venture capitalists, rather than simply increase the quantity of entrepreneurial firms.

Our interpretation of the findings for question one is dependent on the role of networks in venture capital. In particular our understanding of the supply and demand of venture capital investment is dependent on the influence of regional network activity. Our findings in Chapter 5 and 6 strongly suggest that the coefficients of the network variables have a stronger influence on the supply of investment than the demand for investment. As our second thesis research question is also motivated to understand network activity in venture capital, this provides a strong link between our first and second research question. In light of this link between research questions, next, we examine how our research contributes to the understanding of networks and regional advantages. Then we consider the implications of venture capital networks.

10.2.2 Networks and regional advantages

In Chapter 3 we bring together literature on venture capital, regional innovation systems, social network analysis and economic sociology to develop a model which describes the organisation of networks associated with venture capital investment and entrepreneurial firms. At the core of the model is the expectation that networks help link the supply of investment with demand for finance from entrepreneurial firms. For example, the use of this type of network is one way investors are able to share information, collaborate and develop trust based relationships with other investors and entrepreneurial actors. These relationships extend beyond a formal financial connection of simply providing finance to

the same firm and are an important part of establishing the type of social networks described in the literature on clusters and regional innovation systems. Our model in Chapter 3 expects venture capitalists to be important actors in the network, helping to establish effective social networks.

Our analysis broadly supports the model of venture capital networks proposed in Chapter 3. Our findings suggest that investors fulfil a co-ordination role between different firm boards, and ultimately between the directors of these firms. We also find evidence that, in line with the literature, venture capitalists are active investors, connected to the boards of their portfolio firms, building relationships with other board directors. However, we also enhance the model proposed in Chapter 3 by extending our understanding of the sub-structures and different types of relationships that contribute to the overall organisation of venture capital networks.

One implication from our network analysis in Chapter 7 is large investors prefer to build strong relationships with other important investors. This is supported by our findings from Chapter 8 that investors are motivated to form relationships that minimise the risk of investing in hi-tech businesses. On the one hand this motivation drives investors to form relationships with many other investors, as this minimises risk by sharing it with other investors who finance the same firm. On the other, it is to form long term, reciprocated relationships with important or influential investors. As influential investors manage large funds, they reduce their need to join large syndicates for purely financial reasons. Large investors fund multiple opportunities to diversify their portfolio and gain access to superior returns. For these reasons, large investors have a great deal of control over the structure of networks and the flow of information and knowledge. .

In the UK a single group of large investors occupy a very powerful central position in the network. By working together closely, this group of investors control the majority of finance, potentially at the expense of small new entrants. The preference of large influential investors to build strong relationships with their equivalents, results in a core group of closely and strongly linked investors. The preference of influential investors to work together, balanced with the needs of less influential investors to access to this important group, result in a centralised national network structure. Central investors commit the majority of finance in a predominantly generalist approach, operating across all regions of the UK. Central investors prefer to repeatedly use the same investment partners, creating strong repeated relationships. These strong ties are characteristic of trust based

ties that extend beyond formal financial commitments. The strongest ties are generally formed between the large experienced investors. We find weaker, more opportunistic, relationships tie the majority of the smaller investors to the core central group. In contrast to the literature, our findings show small investors compete with each other to syndicate with the large investors, rather than establish smaller local clusters.

Our results from Chapter 10 show the participation of different types of investors varies across regions. The variation in strength and structure of ties at regional level provides a link between the view of venture capital as a nationally organised network of investors, versus a regionally concentrated pattern of investment distribution. Within the national network, regional networks are varied, in terms of the number and more importantly the strength of ties. For example, the network in Cambridge reflects the national network, with national investors playing a strong co-ordination role. In other regions, large private investors are less prominent, or more peripheral. In London and Yorkshire publicly orientated investors dominate the networks. Scotland has ties to an array of different types of investors, from individual angel type investors to overseas banks.

Similarly, we find that the national network described in Chapter 7 highlights a separation between public and private investors. Public investors are only weakly tied to the network through ties with larger private investors. It follows that social connections between these smaller investors are also weak. It points to a lack of integration of smaller investors into the industry. On a regional basis divisions between public and private finance vary; some regions are more dependent on connections between public investors to raise finance.

Our analysis from Chapter 9 also contributes to our understanding of regional variation. In general, entrepreneurial directors operate over more restricted geographies than investors. Networks of biopharmaceutical firm directors are formed around a minority of directors who occupy a large proportion of board positions in our sample group. Like in the venture capital network, we find the director network covers all geographies and is co-ordinated by a central group of mobile directors who define the structure of the director network. In contrast to the venture capital network, in some locations we find evidence of regional concentration in strong and weak ties between directors, which support local network activity. Our analysis emphasises the role of Cambridge acting as a core knowledge base for biotechnology SME directors, supporting actors such as venture capitalists that operate across regions. It indicates that places like Cambridge have a distinct advantage in terms of the flow of knowledge and information around the region and access to top expertise in

managing biotech firms. The analysis shows venture capitalist directors are a strong feature of co-ordination of the network between directors, but are also supported by a variety of other types of supporting actors, providing coverage of a range of competences.

We link the performance of Cambridge in attracting investment activity, with extensive trust based connections between local groups of experienced business people. These trust based ties help structure local networks, as well providing access to large investors in London and overseas. Our analysis of the network structures and sub-structures fits closely with our discussion of social capital theory and entrepreneurial networks in Chapter 3. Similarly, Chapter 10 shows that regional investor and director networks are well connected in the Eastern region. We find the ties between different investment funds, are supported by ties between firm directors. Often these ties involve investment executives, re-enforcing that venture capitalists play an important co-ordination role in the network. We find Cambridge, and networks involving Cambridge firms, act as a central resource for experienced biopharmaceutical directors in the UK; other regions share weak connections to directors of firms in Cambridge to try and access this resource.

In several cases the strength of Cambridge attracts firms from other regional universities to relocate in the area. The relocation of firms from a region diminishes that region's local demand for finance. For firms moving to Cambridge, this strengthens the demand for finance in the East. The added demand of finance can be met through Cambridge's connections to the centre of the supply of venture capital with investors from nearby London.

However, the role of the venture capitalist co-ordinator is only part of the story. In the regional network analysis we find variation in the strategies of venture capitalists. For example, some investors prefer to tie with particular groups of professional biotech directors. The experience of professional directors, who have histories of working in different biopharmaceutical companies, can be used by venture capital firms instead of supplying their own investment executives. This type of strategy matches closely to the career development perspective we discuss in Chapter 3, whereby individuals are motivated by their own career development, and in doing so become valuable directors with a distinctive experiential based expertise or 'business scan'.

We also find relationships between firms that don't fit the expectations developed in Chapter 3. The relationships between firms strongly indicate ties to universities and fit

neither the view of the venture capitalist as co-ordinator, or an individual career development perspective. For example, firms spun-out from Imperial College or Sheffield University, that have remained located in their original region, have also remained close to the finance and expertise offered by their University's technology transfer arms. As both Sheffield and Imperial have publicly floated their technology transfer arm, the relationships associated with ties to these universities blur any traditional boundary between public and private investment, or academic and business activity. The relationship is based on an extended management role of public institutions. This role includes firm creation, promotion of university intellectual property, and a share of the day to day responsibilities of the financial and strategic management of their affiliated firms. These publicly based, but privately financed vehicles have moved into the sphere of venture capital, with first refusal rights to commercialise institutions intellectual property. We find groupings of university affiliated firm groups prominent in our data, in the East, London and Yorkshire. The directors involved in these firms have backgrounds as academic entrepreneurs, investors, and professional directors, as well as legal advisors and employees of university technology transfer offices.

In summary we find a wide variety of relationships in the networks we analyse. In Cambridge, we observe a highly focused region, with strong a strong mix of public and private based support spread throughout the network. At first view Scotland appears as a fragmented network. However, directors of Scottish firms have diverse backgrounds, recruited from other industries, 'borrowed' from other regions, and often co-ordinated by the RDA. In London, and to a limited extent Yorkshire, we find university strategies are prominent whereas traditional private venture capital activity is concentrated to pockets of firms.

We set out to find relationships between venture capitalists, investment executives and firm directors. In doing so, we highlight a contrasting picture between a national versus a regional perspective. At the national level, we observe a strong structure formed around a minority group of large nationally orientated investors, active in a large number of deals. At the regional level we see variation between regions, in terms of the density of connections between private investors, regions without distinctive sector based networks, or those with a greater emphasis on the university as innovator, fundraiser and local co-ordinator.

However, consistent across both the national and regional view, is the lack of integration between the regional actors into the main networks. The investment networks show regional network groups are less visible at a national level. To be sustainable, private investment funds are selective, and this motivates their national orientation to search out promising opportunities and work with other similar national players to diversify their portfolio. Investment tied to specific regions is often formed from small funds involving public finance, with limited opportunity to repeatedly fund their portfolios. Imposing regional restrictions on a fund works against its integration into the national industry structure and limits their participation in financing the minority of firms that are successful. Likewise, we find the structure of the director network is provided by a small group of mobile directors, which outside Cambridge has a weaker regional structure.

Comparing our findings with the literature from Chapter 2 shows some similarity with the model of the organisation of venture capital proposed by Florida and Kenney (1988). Their model emphasised connections between different locations or venture capital complexes, which connect active investors in technology centres, with passive investors in financial centres. However, in this thesis, investors are concentrated around one financial complex, most likely to help fundraising activities, but invest across different locations. Our analysis also indicates rather than being distinct types of complexes, financial and technology activity exist locally, as well as being supported by activities across locations. We find a core group of investors who operate across regional boundaries, as passive and active investors. Our results also provide some indication that investors and directors in the more intensive technology based regions interact with other weaker locations. In our research we find the local social structures of innovation that Florida and Kenney (1988) connect to technology complexes, in fact extend beyond the region.

Similarly, linking to the literature on clusters in Chapter 2 we draw a distinction between the clustering of investment and the clustering of investors. We place less emphasis on the co-location of investors in technology clusters; instead we observe the attractive power of key locations for investment. It maybe a result of smaller geography of the UK, with respect to the US, that means investors prefer to cluster around a single financial centre, and pursue investments across different geographies. A national investor network suggests information on opportunities in all regions should be easily accessible. However, our research indicates that concentrations in investment activity arise as a result of a combination of historically embedded processes, such as investor perceptions of quality and variations in the strength of social ties developed through investment activity. In

biotechnology we find clusters of research activity are important and universities play a key role attracting investment, which to some extent can limit the influence of the historically embedded nature of venture capital.

However, we highlight local variation in network activity. In Scotland, an important venture capital region, regional social structures appear weaker in the biopharmaceutical sector. We find an absence of strongly tied local directors. The performance of Scotland is a result of different processes involving a range of different types of local actors and more formal links to directors in other regions. In Scotland, directors' backgrounds suggest social networks operate across sectors to support local firms. Scotland has been able to attract large pools of investors who operate nationally and internationally, rather than develop strong local investment networks. According to the literature in Chapters 2 and 3, access to venture capital networks is important for regional development. Thus, the Scottish pattern of network activity may result in regional disadvantage in terms of the access and diffusion of new knowledge and information. However, given the level of regional activity in Scotland, there may also be advantages from adopting a distinctly different strategy of network activity compared to places like Cambridge.

10.2.3 How do networks influence investment supply and demand?

In Chapters 5 & 6 we find networking in venture capital supports investment supply more strongly than investment demand. Our detailed analysis of the networks in places like Cambridge show the presence of strong connections with large London based investors, increasing the supply of investment to the region. In other regions our network analysis highlights supply and demand side motivations. For example Imperial Innovations facilitates demand for finance by promoting Imperial College to spin out firms, offering support from a dedicated pool of expertise. It also helps these firms by directly supplying investment capital. In this section we evaluate the role of networks in influencing investment supply and demand.

We have found networking a strong feature of actors in the supply of investment. Chapter 8 demonstrates that strong motivations exist for investors to network in order to increase their own investment supply; sharing the investment burden reduces their risk exposure, and diversifies their portfolio. We expect a large network of active investors, directors and associated actors in a region will have a positive influence on investment supply. Experienced investors and directors with a history of activity in hi-tech business, attached to region's firms, are likely to have extensive networks which can be utilised at a regional

level. We also find the presence of strong relationships between investors, including those overseas, which can be utilised to increase investment supply. We have shown that although the networks for top UK regions are structured differently, they are extensive and include national and overseas investors. Our results strongly suggest that regions with extensive networks will positively influence the supply of regional investment.

We do not anticipate that these networks will influence the demand for finance as strongly. It is possible, that in developing regional networks of investors and directors, the demand for finance is increased. For example, following the theory of social capital, regional networks help entrepreneurs develop an awareness of the requirements of venture capital as a source of funding. Alternatively networks can provide access to experienced business people, including those with previous experience of venture capital, which helps to facilitate a greater demand for finance in the region.

However, assessing the level of demand for venture capital is complex. On a basic level we can see demand as being concerned with any SME looking for investment. However, a general demand for investment might substitute venture capital for different forms of investment or loans. Similarly, it would not make sense to provide finance to all opportunities that demand it. A more appropriate measure of demand regards firms that are appropriate for VC funding or classed as 'investor ready' (Mason and Harrison, 2001). Investor ready businesses have engaged in activities which make the firm attractive for investment, such developing a suitable business plan, or engaging in local networks to seek out advice and access to important resources. The demand from investor ready businesses should be fulfilled, rather than matching the demand for finance from any business. The question is then, how strongly does generating relationships between investors, directors and other active parties increase a region's demand for investment from investor ready opportunities?

Here we find ambiguity. UK investors frequently report that there is large general demand for venture capital as a form of investment, but a lack of investor ready opportunities (McFall, 2004). In contrast, Government sponsored surveys outline that funds connected to public sources have been the majority of incumbents into the UK venture capital industry, with 26% of active funds now involving public contributions (of this 32% are purely public) (DTI, 2005). Furthermore, even in areas targeted by public investment where local investors have been positioned to help develop the relationship between the local business community and investors, such as the North West and East Midlands,

difficulties have arisen in stimulating acceptable demand (DTI, 2005). Similarly, Angel investors, who are generally hands-on investors, report weakness in the quality and presentation of opportunities (DTI, 2005). In summary, we suggest that the factor limiting demand is the quality of opportunities seen by investors. This is supported by the BVCA (2005) promoting that very early stage firms remain in universities, rather than being immediately spun out. In effect, the BVCA are seeking to reduce overall demand for investment deals.

It has been suggested that regions with low levels of venture capital lack deal makers who are able to transform the demands of entrepreneurs into a form acceptable for investors (McFall, 2004). In our network analysis we find that many of the directors with experience, have connections to an investment fund, suggesting the presence of deal makers. We have found that expertise, in terms of directors with experience in serving on biotechnology firm boards, is centred in Cambridge. In Cambridge the increased networking between experienced directors, universities and investors, with the entrepreneurial firms, has helped create an environment supportive to the development of investor ready opportunities. This environment has strengthened the demand from investor ready opportunities in the region.

However, we have also found that experienced actors are often tied to a particular investor, rather than free to network across investors. This reduces the impact that individuals can have in stimulating demand by facilitating connections between entrepreneurs and different investors. We find experienced directors, on balance, are positioned as working for the supply side actors, managing investments, rather than seeking new demand. Similarly, when experienced actors are connected to sources of demand, such as universities, they form isolated groups, which serve the university, rather than the wider region. Therefore, the impact of increasing the size or interconnectivity of actors in local networks will not have an immediate effect on demand for investment; whereas increasing a region's connectivity to investors will influence investment supply. For, example our analysis of Yorkshire, as an embryonic region, shows a lack of international investor activity. Clearly, increasing its networks to include international investors will have a direct impact on regional supply.

The impact of networks on demand will always be secondary to the level of entrepreneurial innovation and creativity that exists in a region. It follows from our discussion of networks and investment demand, that we might expect demand to be stimulated as a

secondary response to increase regional networking. Our results show that networks of directors and investors are formed of supply side actors, many of which have been ‘artificially’ created to provide supply and to stimulate demand through participating in local networks. However, networking alone is not enough to have a large influence on demand. We know that the limiting factor in demand is not that investors lack an awareness of the demand for finance, but concentrate on demand from investor ready opportunities.

It is not enough to expect that increasing the connections between individuals will have an immediate effect on the level of demand. It takes time to create the knowledge and acceptance of working with venture capital. In places like Cambridge the expertise and knowledge required to produce ‘investor ready’ opportunities has been supported by a cumulative generational process based on shared career histories of individuals working in the area. Therefore increased networking is only likely to create stronger demand if it facilitates access to more investment opportunities within the region, and this process is likely to be cumulative. Increasing the size of the networks will introduce new investors to the region who can be expected to readily increase the supply of capital.

We conclude that expanding a region’s network will have a greater and more immediate influence on the potential supply of investment, than on the potential demand for it. Through expanding investors and directors social networks we can expect that investment from regional financial centres will be better integrated, or drawn from further afield. Developing the regional demand for investment is a long term process, which may be aided by developing networks and connecting expertise to a location. Developing networks may help to support the business community and formulate appropriate business plans. These activities may help stimulate demand for venture capital, but ultimately the level of demand depends on a more generational process within the region.

10.3 Government policy and public funding for biotechnology

In this thesis we have found that public finance has been a strong feature in the analysis. A persistent difficulty for investors in biopharmaceutical innovation is that potential returns may not outweigh the large risks of failure. However, in the long term, biotechnology and associated innovations may have large social or national economic returns. Here lies the motivation for Government involvement.

Following Schumpeter (1961), new opportunities are expected to encourage waves of entrepreneurs. However, only the best opportunities obtain finance from private capitalist investors who take on high risk projects anticipating high rewards. Venture capital is expected to fill role of risk based finance as it is strongly driven by profit motivations. VC should carefully select the opportunities to finance. Venture capitalists fund a minority of the opportunities they encounter; only the highest quality opportunities stand a chance of being funded. The risk of using public finance to support SME is that many firms are encouraged that have only a very small chance of accessing follow-on funding, and are potentially inappropriate for larger investment from private venture capitalists.

We find in some cases public finance has been provided to firms which have also attracted investment from the private sector. In other cases public finance has attracted further public investment. We do not find a strong involvement of Regional Venture Capital Funds (RVCF) in our data. The Government's role appears to be more successful for encouraging venture capital investment in biopharmaceuticals, when public money is directed towards R&D. Investing in basic research has the expectation that this will stimulate demand for investment.

The major issue here is what is the role of government? We find public money is used on the supply side to provide high risk seed finance. Seed finance is used to move new start-ups beyond proof of concept, or to reach a position where they can approach private investors for funding. This suggests public seed funds are a tool to encourage further investment supply, bridging a gap in the market. However our analysis suggests that simply increasing public finance may not be beneficial overall. For example, existing private investors remain tied to different opportunities and we observe weak integration between public and private funds. In contrast to public venture capital, we find the strongest integration of public and private finance in the investment networks is where firms have receive direct public investment in the form of DTI grants.

Similarly, the creation of regional or university funds has not resulted in strong integration between public and private investment sources, despite being a justification for their creation. Local sources are predominantly public, and tied to a single location. Like all funds, public funds must syndicate to invest in high risk opportunities. However, if public funds invest in high risk projects, on a commercial basis, then they must be selective to ensure they can back the opportunity through each investment round, or else face excessive dilution. In contrast, private investors are nationally orientated, free to access the best

opportunities wherever located, and have access to large amounts of finance from similarly sized and trusted partners.

This thesis has also described new institutional forms which operate with the dual purpose of stimulating investment demand and creating their own supply of investment. Typically financed with private capital, University IP (Intellectual Property) management companies are more integrated with private investors, but not necessarily with venture capitalists finance or expertise. The difficulties associated with information asymmetries in early stage biopharmaceutical firm investment have been overcome by raising finance on the back of an IP portfolio covering years of university research output. IP management companies, raising small investment funds, may be a solution for the transfer of university research from public to private sphere. However, their sustainability, as for the other smaller sized funds, will depend on their ability to support the development of their portfolio and integrate with other private investors.

One difficulty with the UK policy on biotechnology clusters and venture capital is that these policies work against the preference of the private investors. The literature describes clusters and venture capital as operating in close proximity, using social networks to exchange information and knowledge, as well as provide access to resources such as influential human capital. In regions such as Cambridge, we can recognise this description of the clustering of investment, firms, networks and influential individuals, acting as a magnet for high tech activity and those interested in working in it. However, a secondary aim of Government policy is to distribute the supply of investment more evenly. This also supports other regionally distributive policies such as the creation of regional bioclusters. A policy of regional cluster creation naturally expects further distribution of investment funds. However, we have found in general, UK venture capital activity is persistently concentrated into a few locations. Investors are based in London and to a large extent investment is concentrated in regions around London.

Stimulating the formation of bio clusters in other locations presents difficulties in bringing together the system to support new firms. We see that Cambridge acts as a central resource for expertise in biopharmaceutical firms and has established links with investors in London and internationally, as well as having a core of locally based investors. Other regions have weaker access to experienced directors or locally based private investors, so compete to access resources in Cambridge. On the other hand, firms that move to

Cambridge, weaken networks in their home region, and are often unable to benefit from the network connections utilised by firms with local Cambridge origins.

To be a sustainable, bioclusters need to develop access to investment and expertise. To support embryonic locations public finance is supplied to the region with the goal of providing access to funding and expertise. The weakness we consistently observe is that public finance only partially integrates with private players⁴³. We frequently find that private finance is concentrated into a minority of firms, managed by the experienced investors and directors. In contrast locally constrained public based funds operate with fund sizes that can only support the first steps of firm development. In regions receiving public funds, few of the associated firms are tempting prospects to private investors, raising the question of whether pump-priming policies are effective in the long term, or work against the dynamics of the industry. It is interesting to observe that our analysis of biopharmaceuticals indicates policy action on demand side activity, such as investment in R&D, is more effective than supply side initiatives such as increasing public finance.

Our analysis is concerned with recent years, in terms of activity and policy. Since work began on this thesis, the funding environment had changed; global financial liquidity has reduced following the financial services losses associated with sub-prime mortgages in the US, with repercussions for access to finance for firms seeking IPO. Amongst this background, investors who are central to venture capital, albeit with a decreasing early stage focus, have announced their continued movement away from venture capital. This includes firms like 3i, with speculation that they will close their Cambridge office. Similarly other major investors, such as Chris Evans of Merlin Biosciences, have warned that now is 'crunch time' for UK Biotech (Highfield, 2008), with declining investment, limited access to financial markets, the credit constraints of 2008, mean biotech's have limited options.

These conditions make the environment very tough for SME biopharmaceutical firms. Only the best quality opportunities will have access to significant private finance. The risk is that public finance will support weaker opportunities, which reduces the chance of these funds becoming self sustainable. The DTI (2005) report stresses that public entrants are serving a different section of the market from private investors, such that public investment is not substituted for private. Thus the Government argues that businesses are being

⁴³ Unlike in the Israeli Yozma funds discussed in chapter 8

funded that would otherwise struggle to obtain finance. In contrast, the BVCA (2005), commenting on recent policies to promote demand for venture capital, urge firms to remain within universities until they are at a more advanced stage. The limiting factor in developing venture capital is stimulating the quality of demand. Venture capital is an important part of the regional innovation system, but operates within that system, and attention should be directed towards improving the quality of the demand.

Our analysis shows that in the long term, venture capital does not spread evenly, and attempts to achieve this in the UK are unrealistic. Historically, some publicly created entities have been successful. For example, one response to the perception of an equity gap for financing smaller firms was 3i. 3i has eventually moved from investing in many small deals to moving towards large deals, and has been successful in doing so. Despite having coverage of the UK, 3i's investment was still concentrated to the South.

As incumbents move into bigger private equity investments, we find new entrants are adopting new investment models raising finance by auctioning rights to University intellectual property. However to be sustainable, particularly in sectors like biopharmaceuticals, large private follow-on investment will be necessary, signalling a need to access to overseas finance. We have consistently referred to London as the home of investors and Cambridge as source of expertise in commercialising biotech firms. We find some actors operate across regional borders, connected to firms in Scotland and Yorkshire. However, we can anticipate that any downturn in financial activity will be felt most strongly in those regions without the global contacts and access to finance. It calls into question whether investigation of alternative strategies might be appropriate, and that not every UK region can support a US style biotech cluster.

This thesis supports the use of regional innovation systems thinking in UK innovation and entrepreneurship policy. However, it must be applied to support activities occurring within each region, rather than as a national prescription applied locally. Policy must be used to achieve a balance: encouraging connections between the different locally based actors, without denying connections to actors based in other locations across the world. This type of system, akin to small world networks, can balance locally generated support with access to new expertise and knowledge generated in other national and international locations. Systems must be designed to promote quality, rather than quantity. The extensive use of public funds on the supply and demand side of our regional analysis generates lots of opportunities, which risk demanding finance from public sources, rather than private. In

the long term this is unsustainable. Regional innovation systems need to promote demand from high quality opportunities to stimulate private investment.

11 References

- Admati, A.R. and Pfleiderer, P. (1994) 'Robust financial contracting and the role of Venture Capitalists', *The journal of finance*, Vol. 49, No. 2, pp.371-402.
- Amin, A. and Thrift, N. (1992) 'Neo-Marshallian nodes in global networks', in Bryson, J., Henry, N., Keeble, D. and Martin, R. (1999) (eds.) *The economic geography reader*, (pp.175-182), Chichester, UK, John Wiley and Sons.
- Arrow Therapeutics (no date). Investment history. Available from: <http://www.arrowt.co.uk/invmedia-current.htm> (Accessed 3rd April 2008).
- Athreye, S. (2004) 'Agglomeration and growth, a study of the Cambridge high-tech cluster', in Bresnahan, T. and Gambardella, A. (eds.) *Building high-tech clusters*, (pp.121-159), Cambridge, Cambridge University Press.
- Audretsch, D.B. and Feldman, M.P. (1996) 'R&D spillovers and the geography of innovation and production', *The American economic review*, Vol. 86, No. 3, pp.630-640.
- Audretsch, D.B. and Stephan, P.E. (1996) 'Company-scientist locational links: The case of Biotechnology', *The American economic review*, Vol. 86, No. 3, pp.641-652
- Bagchi-Sen, S., Smith, H. and Hall, L. (2004) 'The US Biotechnology industry: Industry dynamics and policy', *Environment and planning C: government and policy*, Vol. 22, pp.199-216.
- Bahrami, H. and Evans, S. (1995) 'Flexible recycling and high technology entrepreneurship', in Kenney, M (ed.) (2000) *Understanding Silicon Valley*, (pp.165-189), Stanford University Press, Stanford
- Baltagi, B.H. (2005) *Econometric analysis of panel data*, Chichester, UK, John Wiley & Sons Ltd.
- Barabási, A. L. (2002) *Linked. How everything is connected to everything else and what it means for business, science and everyday life*, London, Penguin.
- Barabási, A. L. Albert, R. (1999) 'Emergence of scaling in random networks', *Science*, Vol. 286. No. 5439, pp.509-512
- Batt, C. (2003) 'Stagecoach founders raise stake 26pc', *The Telegraph*, 31st January, [online] Available from: <http://www.telegraph.co.uk/money/main.jhtml?xml=/money/2003/02/01/cncoach01.xml>. (Accessed 22 April 2008)
- Bioscience Innovation and Growth Team (2003) *Bioscience 2015 improving national health, improving national wealth*, London, Department of Trade and Industry
- Boone, J. (2006) 'University Company Sells Stake for £25m', *The Financial Times*, 21st July [online] Available from: <http://www.ft.com/cms/s/0/bb2d01d0-1855-11db-99a6-0000779e2340.html> (Accessed 25 March 2007).

- Bourdieu, P. (1986) 'The forms of capital', in Richardson, J.G. (1986) (ed.) *Handbook of theory and research for the sociology of education*, (pp.241-258), New York, Greenwood
- Bower, D.J. (2003) 'Business model fashion and the academic spin out', *R&D management*, Vol. 33, No. 3, pp.97-106.
- Boyd, B. (1990) 'Corporate linkages and organizational environment: A Test of the Resource Dependence Model', *Strategic management journal*, Vol. 11, No. 6, pp.419-430
- Brander, J.A., Amit, R. and Antweiler, W. (2002) 'Venture-Capital syndication: Improved venture selection vs. the value-added hypothesis', *Journal of economics & management strategy*, Vol. 11, No. 3, pp.423-452
- Brink, J., McKelvey, M. and Smith, K. (2004) 'Conceptualizing and measuring modern biotechnology', in McKelvey, M., Rickne, A. and Laage-Hellman, J. (eds.) *The economic dynamics of modern Biotechnology*, Cheltenham, Edward Elgar.
- British Venture Capital Association, (2003) *Report on investment activity*, BVCA, London.
- British Venture Capital Association, (2005) *Creating success from university spin outs*, BVCA, London.
- British Venture Capital Association (2006) *Private Equity and Venture Capital performance measurement Survey*, BVCA, London
- Bockholt, P. and de Jager, D. (2004) 'South East Brabant: A regional innovation system in transition', in Cooke, P. Heidenreich, M. Braczyk, H.J. (eds.) *Regional innovation systems: The role of governances in a globalised world*, Oxford, Routledge
- Brüderl, P. and Preisendörfer, P. (1998) 'Network Support and the Success of Newly Founded Businesses', *Small business economics*, Vol. 10, pp.213-225.
- Buam, J.A.C. and Silverman, B.S. (2004) 'Picking winners or building them? Alliance, intellectual, and human capital as selection criteria in venture financing and performance of biotechnology start-ups', *Journal of business venturing*, No.19, p.411-436.
- Burt, R.S. (1992) *Structural holes: the social structure of competition*, London, Harvard University Press.
- Burton, M.D., Sorenson, J.B. and Beckman, C.M. (2002) 'Coming from Good Stock: Career Histories and New Venture Formation', in Lounsbury, M. and Ventresca, M (eds), *Research in the sociology of organizations, volume: Social structure and organizations revisited*, JAI Press pp.229-262
- Bygrave, W.D. (1987) 'Syndicated investments by venture capital firms: A networking perspective'. *Journal of business venturing*, Vol. 2, No. 2, pp.139-154
- Bygrave, W.D. (1988) 'The structure of the investment networks of venture capital firms', *Journal of business venturing*, Vol. 3, pp.137-157.
- Bygrave, W.D. Timmons, J.A. (1992) *Venture capital at the crossroads*, Boston, Harvard Business School Press.

Byrne, J.A. (2000) 'How a VC does it', *Business week*, 24th July [online] Available from: http://www.businessweek.com/2000/00_30/b3691001.htm (Accessed 21 June 2007)

Campbell, K. (2003) *Smarter ventures: A survivor's guide to venture capital through the new cycle*, Harlow, UK, Financial Times Prentice Hall.

Cantwell, J and Iammarino, S. (2002) 'Multinational corporations and the location of technological innovation in the UK regions', *Regional Studies*, Vol.34, No.4, pp.317-322.

Castilla, E.J., Hwang, H., Granovetter, E. and Granovetter, M. (2000) 'Social networks in Silicon Valley', in Lee, C.M., Miller, W.F., Hancock, M.G. and Rowen, H.S (eds.) *The Silicon Valley edge: A habitat for innovation and entrepreneurship*, (pp.218-247), Stanford, Stanford University Press.

Chipman, A. (2006) 'Capital gains', *Nature*, Vol. 443, p.897.

Chipman, A. (2007) 'London calling', *Nature*, Vol. 447 p.367

Cohen, S.S. and Fields, G. (1999) 'Social capital and capital gains: An examination of social capital in Silicon Valley' in Kenney, M (2000) (ed.) *Understanding Silicon Valley*, Stanford, Stanford University Press.

Coleman, J.S. (1990) *Foundations of social theory*, Cambridge Massachusetts, Harvard University Press.

Canyon, M.J. and Muldoon, M.R. (2006) 'The small world of corporate boards', *Journal of business finance & accounting*, Vol. 33, No. 9/10, pp.11321-1343.

Cooke, P. (2003) 'The evolution of biotechnology in three continents: Schumpeterian or Penrosian?', *European Planning Studies*, Vol. 11, No. 7, pp.757-763.

Cooke, P. (2004) 'Regional knowledge capabilities, embeddedness of firms and industrial organisations: bioscience Megacentres and economic geography', *European planning studies*, Vol. 12, No. 5 pp.625-641.

Cooksey, D. (2006) *A review of UK health funding*, HM Treasury, HMSO, London

Cowling, M. Mitchell, P. (1997) 'The evolution of UK self employment: A study of government policy and the role of the macro economy', *The Manchester school*, Vol. LXV, No.4

Cumming, D.J. (2006) 'The determinants of venture capital portfolio size: Empirical evidence', *Journal of business*, Vol. 79, No. 3, pp.1083-1126.

Daily, C.M. Dalton, D.R. (1992) 'The relationship between governance structure and corporate performance in entrepreneurial firms', *Journal of business venturing*, Vol. 7, pp.375-386.

Daily, C.M. Dalton, D.R. (1993) 'Board of directors leadership and structure: Control and performance implications', *Entrepreneurship theory and practice*, Vol. 17, No. 3, pp.65-81.

- Davoudi, S. (2007) The 'Godfather' of UK biotech, *The Financial Times*, 8th March, [Online] Available from: <http://www.ft.com/cms/s/0/aecd1afe-cd1a-11db-a938-000b5df10621.html> (Accessed 8 June 2008).
- De Nooy, W., Mrvar, A. and Batagelj, V. (2005) *Exploratory social network analysis with Pajek*, Cambridge, Cambridge University Press.
- Deakins, D., O'Neill, E. and Mileham, P. (2000) 'Executive learning in entrepreneurial firms and the role of external directors', *Education + Training*, Vol. 42, No. 4/5, pp.317-325
- Donckels, R. and Lambrecht, J. (1995) 'Networks and small business growth: An explanatory model', *Small business economics*, Vol. 7, pp.273-289.
- Dooley, P.C. (1969) 'The interlocking directorate', *The American economic review*, Vol. 59, No. 3, pp.314-323
- Dossani, R. and Kenney, M. (2002) 'Creating an environment for Venture Capital in India', *World development*, Vol. 30, No. 2, pp.227-253
- DrugResearcher.Com (July 2004) *CellFactors enters administration*, Available from: <http://www.drugresearcher.com/news/ng.asp?id=53911> (Accessed 21 March 2008).
- Druilhe, C. and Garnsey, E. (2000) 'Emergence and growth of high-tech activity in Cambridge and Grenoble', *Entrepreneurship & regional development*, Vol. 12, pp.163-177.
- DTI (2001) Business clusters in the UK: A first assessment. [Online] Available from: <http://www.berr.gov.uk/regional/clusters/clusters-assessment/page17380.html> (Accessed 5 May 2008).
- Etzkowitz, H. (2005) 'The renewal of venture capital: Toward a counter-cyclical model', *Technology analysis and strategic management*, Vol. 17, No. 1, pp.73-87
- Eurostat database [online]. Available from: <http://www.eurostat.eu> (Accessed Feb 2006 – April 2008)
- FAME [online] Available from: <http://www.bvdep.com/en/fame.html> Accessed Feb 2006 - April 2008
- Feldman, M.P. and Francis, J.L. (2003) 'Fortune favours the prepared region: The case of entrepreneurship and the Capitol region biotechnology cluster', *European planning studies*, Vol. 11, No. 7, pp.765-788.
- Finke, T.A. (1998) 'The relationship between boards of directors and initial public offerings in the biotechnology industry', *Entrepreneurship, theory and practice*, Vol.22, pp.5-29.
- Florida, R. (2002) 'The economic geography of talent', *Annals of the association of American geographers*, Vol. 92, No. 4, pp.743-755.

Florida, R. and Smith, D. (1993) 'Venture capital formation, investment, and regional industrialization', *Annals of the association of American geographers*, Vol. 83, No. 3, pp.434-451.

Florida, R.L. and Kenney, M. (1986) 'Venture capital, high technology and regional development', *Regional studies*, Vol. 22, No. 1, pp.33-48.

Florida, R.L. and Kenney, M (1988) 'Venture capital-financed innovation and technological change in the USA', *Research Policy*, Vol. 17, pp.119-137.

Fortson, D (2008) 'Crunch time for tech start-ups as 3i quits sector', *The Independent*, London, March 26th, p.38.

Galapagos N.V. (2006) Galapagos to acquire Inpharmatica. [online] Available from: <http://www.glpag.com/press/2006/26.pdf> (Accessed 10 April 2008)

Garner, C. Marchington, T. Pfeifer, A. (2006) 'Key ingredients for success in Europe', *Nature bioentrepreneur*, [online] Available from: http://www.nature.com/bioent/building/entre/022007/pf/bioent917_pf.html (Accessed 14 March 2008).

Garnsey, E. and Heffernan, P. (2005) 'High-technology clustering through spin-out and attraction: The Cambridge case', *Regional studies*, Vol.39, No.8, pp.1127-1144.

Gertler, M.S. and Levitte, Y.M. (2005) 'Local nodes in global networks: The Geography of knowledge flows in biotechnology innovation', *Industry and Innovation*, Vol. 12, No. 4, p.487-507.

Gompers, P.A. (1995) 'Optimal investment, monitoring, and the staging of capital', *The journal of finance*, Vol.L, No.5, pp.1461-1489.

Gompers, P.A. and Lerner, J (1999) 'What drives venture capital fundraising?', Available from: <http://ssrn.com/abstract=57935> (Accessed 10 March 2008).

Gompers, P.A. and Lerner, J (2000) 'Money chasing deals? The impact of fund inflows on private equity valuation', *Journal of financial economics*, Vol.55, No.2, pp.281-325.

Gompers, P.A. and Lerner, J (2001) 'The venture capital revolution'. *Journal of economic perspectives*, Vol.15, No.2, pp.145-168.

Gorman, M. and Sahlman, W.A. (1989) 'What do venture capitalists do?', *Journal of business venturing*, Vol. 4, pp.231-248.

Gorton, M. (1999) 'Spatial variations in markets served by UK-based small and medium-sized enterprises (SMEs)', *Entrepreneurship & regional development*, Vol. 11, No. 1, pp.39-55.

Guthrie, J. (2007) 'Warning of 'disaster' for Silicon Fen', *The Financial Times*, 15th November [online] Available from: <http://www.ft.com/cms/s/0/d7829f3c-9308-11dc-ad39-0000779fd2ac.html> (Accessed 10 April 2008)

Grandori, A. and Soda, G. (1995) 'Interfirm networks antecedents, mechanisms and forms', *Organisation studies*, Vol. 16, No. 2, pp.183-214.

Granovetter, M.S. (1973) 'The strength of weak ties', *The American journal of sociology*, Vol. 78, No. 6, pp.1360-1380.

Granovetter, M.S. (1985) 'Economic action and social structure: The problem embeddedness', *The American journal of sociology*, Vol. 91, No. 3, pp.481- 510.

Green, M.B. (1983) 'The interurban corporate interlocking directorate network of Canada and the United States: A spatial perspective', *Urban geography*, Vol. 4, No. 4, pp.338-354.

Greve, A. and Salaff, J.W. (2003) 'Social networks and entrepreneurship', *Entrepreneurship theory and practice*, Vol. 28, No.1, pp.1-22.

Griffith, T. Yam, P. Subramaniam, S. (2007) 'Silicon Valley's 'One-hour'' distance rule and managing return on location', *Venture capital: An international journal of entrepreneurial finance*, Vol. 9, No. 2, pp.85-106.

Guler, I. and McGahan, A.M. (2006) 'Syndication in international venture investing', Working paper, London Business School, Available from: <http://facultyresearch.london.edu/> (Access 21 April 2008).

Gulati, R. (2007) *Managing network resources: Alliances, affiliations and other relational assets*, Oxford, Oxford University Press.

Gulati, R. and Higgins, M.C. (2003) 'Which ties matter when? The contingent effects of interorganizational partnerships on IPO success', *Strategic management journal*, Vol. 24, pp.127-144.

Gurău, C. (2006) 'Bioentrepreneurs in different economic systems: a comparative analysis of bio-entrepreneurs' profiles in UK, France and Germany', *International journal of biotechnology*, Vol. 8, No. 3-4, pp.169-186.

Harris, I.C. and Shimizu, K. (2004) 'Too busy to serve? An examination of the influence of overboarded directors', *Journal of management studies*, Vol.41, No.5, pp.775-798.

Henderson, R., Orsenigo, L. and Pisano, G.P. (1999) 'The pharmaceutical industry and the revolution in molecular biology; interactions among scientific, organisational, and institutional change', in Mowery, D.C. and Nelson, R.R. (eds.) *Sources of industrial leadership*, (pp.267-311), Cambridge, Cambridge University Press.

Hellman, T. and Puri, M. (2002) 'Venture capital and the professionalization of start-up firms: Empirical evidence', *Journal of finance*, Vol. LVII, No.1, pp.169-197.

Higgins, M.C. (2005) *Career imprints. Creating leaders across an industry*, San Francisco, Jossey-Bass.

Higgins, M. C. and Gulati, R. (2003) 'Getting off to a good start: The effects of upper echelon affiliations on underwriter prestige', *Organization science*, Vol. 14, No. 3, pp.244-263.

- Hochberg, Y.V., Ljungqvist, A. and Yang, L (2007) 'Whom you know matters: Venture capital networks and investment performance', *The journal of finance*, Vol. 62, No.1, pp.251-301.
- Hochberg, Y., Ljungqvist, A. and Lu, Y. (May 2007) 'Networking as a barrier to entry and the competitive supply of venture capital', Available from: <http://ssrn.com/abstract=923824> (Accessed 30 May 2007)
- Hood, N. (2000) 'Public venture capital and economic development: The Scottish experience', *Venture capital: An international journal of entrepreneurial finance*, Vol. 2, No. 4, pp.313-341.
- Howell, M., Trull, M. and Dibner, M.D. (2003) 'The rise of European venture capital for biotechnology', *Nature biotechnology*, Vol. 21, No.11, pp.1287-91.
- Hsu, D.H. and Kenney, M. (2005) 'Organizing venture capital: The rise and demise of American Research and Development Corporation 1946-1973', *Industrial and corporate change*, Vol. 14, No. 4, pp.579-616.
- Iammarino, S. and McCann, P. (2006) 'The structure and evolution of industrial clusters: Transactions, technology and knowledge spillovers', *Research Policy*, Vol. 35, pp.1018-1036.
- Jaffe, A.B., Trajtenberg, M. and Henderson, R. (1993) 'Geographical localization of knowledge spillovers as evidenced by patent citations', *The quarterly journal of economics*, Vol. 108, No. 3, pp.577-598.
- Jeng, L. and Wells, P. (2000) 'The determinants of venture funding: evidence across countries', *Journal of corporate finance*, Vol.6, pp.241-289.
- Johnson, J.L., Daily, C.M. and Ellstrand, A.E. (1996) 'Boards of directors: A review and research agenda', *Journal of management*, Vol. 22, No.3, pp.409-438.
- Kaplan, S.N., Strömberg, P.J. and Sensoy, B.A. (September 2002) 'How well do venture capital databases reflect actual investments?' [online] Available from: <http://ssrn.com/abstract=939073> (Accessed 27 February 2007)
- Kaufmann, D., Schwartz, D., Frenkel, A. and Shefer, D. (2003) 'The role of location and regional networks for biotechnology firms in Israel', *European planning studies*, Vol. 11, No. 7, p.823-840.
- Keeble, D., Lawson, C., Moore, B. and Wilkinson, F. (1999) 'Collective learning processes, networking, and "institutional thickness" in the Cambridge region', *Regional studies*, Vol. 33, No. 4, pp.319-332.
- Kennedy, P. (2003) 'A Guide to Econometrics', (5th Edition), Oxford, Blackwell Publishing.
- Kenney, M. (1986) 'Schumpeterian innovation and entrepreneurs in capitalism: A case study of the U.S. biotechnology industry', *Research policy*, Vol.15, pp.21-31.
- Kenney, M. and Patton, D. (2004) 'Entrepreneurial geographies: Support networks in three high-tech industries', *Unpublished manuscript*.

- Knoke, D. and Kuklinski, J.H. (1982) *Network analysis*, London, Sage Publications.
- Kogut, B., Urso, P. and Walker, G. (2005) 'The emergent properties of a new financial market: American venture capital syndication from 1960 to 2005', *Management science*, Vol. 53, No. 7, pp.1181-1198.
- Kono, C. Palmer, D., Friedland, R. and Zafonte, M. (1998) 'Lost in space: The geography of corporate interlocking directorates', *American journal of sociology*, Vol. 103, No. 4, pp. 863–911.
- Larson, A. and Starr, J.A. (1993) 'A network model of organizational formation', *Entrepreneurship Theory and Practice*, Vol. 17, Winter, pp.5-15.
- Lerner, J. (1994) 'The syndication of venture capital investments', *Financial management*, Vol. 23, No. 3, pp.16-27.
- Lerner, J. (1995) 'Venture capitalists and the oversight of private firms', *The journal of finance*, Vol. 50, No.1, pp.301-318.
- Leibovitz, J. (2004) 'Embryonic' knowledge-based clusters and cities: The case of biotechnology in Scotland', *Urban studies*, Vol. 41, No. 5/6, pp.1133-1155.
- Library House (2008) 'Does VC need fixing', *Essential intelligence weekly*, No.105, 29th April. Available from: www.libraryhouse.net (Accessed 29 April 2008)
- Library House (2006) *Library House Private Company Intelligence database*, Available from: www.libraryhouse.net. (Accessed September 2006).
- LifeScience CLUSTERS (2007) *LifeScience CLUSTERS*, Vol.1 No.1. Horsham, Avakado.
- Long, J.S. (1997) 'Regression models for categorical and limited dependent variables', London, Sage Publications.
- Lin, N. (2001) 'Social Capital. A theory of social structure and action', Cambridge, UK, Cambridge University Press.
- Lockett, A., Murray, G. and Wright, M. (2002) 'Do UK venture capitalists still have a bias against investment in new technology firms', *Research policy*, Vol. 31, pp.1009-1030.
- Lockett, A. and Wright, M. (2001) 'The syndication of venture capital investments', *Omega*, Vol. 29, pp.375-390.
- Manigart, S., De Waele, K., Wright, M., Robbie, K., Desbrieres, P., Sapienza, H.J. and Beekman, A. (2002) 'Determinants of required return in venture capital investments: A five country study', *Journal of business venturing*, Vol. 17, No. 4, pp.291-312.
- Manigart, S., Lockett, A., Meuleman, M., Wright, M., Landström, H., Bruining, H., Desbrières, P. and Hommel, U. (2006) 'Venture capitalists' decision to syndicate', *Entrepreneurship theory and practice*, Vol. 30, No. 2, pp.131-153.

- Martin, R. (1989) 'The growth and geographical anatomy of venture capitalism in the United Kingdom', *Regional studies*, Vol. 23, No.5, pp.389-403.
- Martin, R. (1999) (ed.) 'Money and the space economy', Chichester, John Wiley & Sons Ltd.
- Martin, R., Berndt, C., Klagge, B. and Sunley, P. (2005) 'Spatial proximity effects and regional equity gaps in the venture capital market: evidence from Germany and the United Kingdom', *Environment and planning A*, Vol. 37, pp.1207-1231.
- Martin, R., Sunley, P. and Turner, D. (2002) 'Taking risks in regions: the geographical anatomy of Europe's emerging venture capital market', *Journal of economic geography*, Vol. 2, No. 2, pp.121-150.
- Mason, C.M. and Harrison, R.T. (2001) Investor readiness: A critique of Government proposals to increase the demand for venture capital, *Regional studies*, Vol. 35, No.8, pp.663-668.
- Mason, C.M. and Harrison, R.T. (2002) 'Barriers to investment in the informal venture capital sector', *Entrepreneurship and regional development*, Vol. 14, pp.271-287.
- Mason, C.M. and Harrison, R.T. (2002) The geography of venture capital investments in the UK, *Transactions of the Institute of British Geographers*, Vol. 27, No.4, pp.428-451.
- Mason, C.M. and Harrison, R.T. (2003) 'Closing the regional equity gap? A critique of the Department of Trade and Industry's regional venture capital funds initiative', *Regional studies*, Vol. 37, No. 8, pp.855-868.
- Massey, D., Quintas, P. and Wield, D. (1992) *High-tech fantasies: Science parks in society, science and space*, London, Routledge.
- Mayer, C., Schoors, K. and Yafeh, Y. (2005) 'Sources of funds and investment activities of venture capital funds: Evidence from Germany, Israel, Japan and the UK', *Journal of corporate finance*, Vol.11, pp.586-608.
- McFall, J (2004), *Regional productivity: oral and written evidence. House of Commons papers 2004-05 501*, Great Britain Parliament House of Commons Treasury Committee minutes, The Stationary Office, London
- McKelvey, M. (1996) *Evolutionary innovations: The business of biotechnology*, Oxford, Oxford University Press.
- McKelvey, M., Rickne, A. and Laage-Hellman, J. (2004) 'Stylized facts about innovation processes in modern biotechnology', in McKelvey, M., Rickne, A. and Laage-Hellman, J. (eds.) *The economic dynamics of modern biotechnology*, (p.43-75), Cheltenham, UK, Edward Elgar.
- McMeekin, A. and Green, K. (2002) 'The social and economic dimensions of biotechnology: An introduction', *New genetics and society*, Vol. 21, No. 2, pp.101-108.
- Mizruchi, M.S. (1996) 'What do interlocks do? An analysis, critique, and assessment of research on interlocking directorates', *Annual review of sociology*, Vol. 22, pp.271-298.

- Morosini, P. (2004) 'Industrial clusters, knowledge integration and performance.' *World development*, Vol. 32, No. 2, pp.305-326.
- Moulton, B.R. (1990) 'An illustration of a pitfall in estimating the effects of aggregate variables on micro units', *The review of economics and statistics*, Vol. 72, No. 2 pp.334-338.
- Medical Research Council (no date) [online] <http://www.mrc.ac.uk/AboutUs/index.htm>. (Accessed 22 April 2008).
- Murray, G. (1999) 'Early stage venture capital funds, scale economies and public support', *Venture capital*, Vol. 1, No. 4, pp.351-384.
- Myint, Y.M., Vyakarnam, S. and New, M.J. (2005) 'The effect of social capital in new venture creation: the Cambridge high-technology cluster', *Strategic change*, Vol. 14, pp.165-177.
- Mytelka, L.K. (2004) 'Clustering, long distance partnerships and the SME a study of the French biotechnology sector', *International journal of technology management*, Vol. 27, No.8, p.791-807.
- Nahapiet, J. and Ghoshal, S. (1998) 'Social capital, intellectual capital and the organisational advantage', *The academy of management review*, Vol. 23, No. 2, pp.242-266.
- Nicholson, G.J., Alexander, M., and Kiel, G.C. (2003) 'Defining the social capital of the board of directors: An exploratory study', *Journal of the Australian and New Zealand Academy of management*, Vol. 10, No. 1, pp.54-72.
- New, M.J. (2003) *Interlocking directorships and the role of the individual in the biotech clusters of Cambridge and London*, MBA dissertation, Judge Institute of Management Studies, University of Cambridge
- Niosi, J. (2003) 'Alliances are not enough explaining rapid growth in biotechnology firms,' *Research policy*, Vol. 32, pp.737-750.
- Niosi, J. and Banik, M. (2005) 'The evolution and performance of biotechnology regional systems of innovation', *Cambridge journal of econometrics*, Vol. 29, pp.343-357.
- Northrup, J. (2005) 'The pharmaceutical sector', in Burns, R. L. (ed.), *The business of healthcare innovation*, Cambridge, Cambridge University Press.
- Norton, E. and Tenenbaum, B.H. (1993) 'Specialization versus diversification as a venture capital investment strategy', *Journal of business venturing*, Vol. 8 pp.431-442.
- Oakey, R.P. (2003a) 'Funding innovation and growth in UK new technology-based firms: some observations on contributions from the public and private sectors' *Venture capital*, Vol.5, No.2, pp.161-179.
- Oakey, R.P. (2003b) 'Technical entrepreneurship in high technology small firms: Some observations on the implications for management', *Technovation*, Vol.23, pp.679-688.

- Oakey, R.P. and Muhktar, S.M (1999) 'United Kingdom high-Technology small firms in theory and practice: A review of recent trends', *International small business journal*, Vol.17, No.2, pp.48-64.
- O'Hagan, S.B. and Green, M.B. (2004) 'Corporate knowledge transfer via interlocks: A network analysis approach', *Geoforum*, Vol. 35, pp.127-139.
- Papaioannou, T. (2006) 'Public-private collaboration in genomics and biotechnology: The cases of Cambridge and Scotland', IKD Working Paper No.21, Available from: <http://www.open.ac.uk- IKD: Innovation, Knowledge and Development- Working Papers>
- Pesaran, M.H. and Smith, R. (1995) 'Estimating long-run relationships from dynamics heterogeneous panels', *Journal of econometrics*, Vol. 68, pp.79-113.
- Pesola, M. (2005a) Nurturing entrepreneurs: The fertile soil of Silicon Fen', *The Financial Times*, 9th February. [Online] Available from: <http://www.ft.com/cms/s/0/bad088f6-7a40-11d9-9b93-00000e2511c8.html>. (Accessed 15 January 2007)
- Pesola, M. (2005b) 'Fen tries to be a valley, *The Financial Times*, 16th February. [Online] <http://www.ft.com/cms/s/0/6a0bf9a2-7fc0-11d9-8ceb-00000e2511c8.html>. (Accessed 15 January 2007)
- Pfeffer, J. (1987) 'A resource dependence perspective on intercorporate relations', in Mizruchi, M.S. and Schwartz, M. (eds.) *Intercorporate relations, the structural analysis of business*, Cambridge, Cambridge University Press, pp.25-55.
- Pfeffer, J. and Salancik, G.R. (1978) *The external control of organizations: A resource dependency perspective*, New York, Harper and Row.
- Pisano, G.P. (2006) *Science business: The promise, the reality, and the future of biotech*, Boston, Massachusetts, Harvard Business School Press.
- Putnam, R.D. (1993) 'The prosperous community: Social capital and public life', *The American prospect*, Vol. 13, pp.35-42.
- Putnam, R.D. (1995) 'Bowling alone: America's declining social capital', *Journal of democracy*, Vol. 6, No.1, pp.65-78.
- Porter, M. (1990) *The competitive advantage of nations*, London, Palgrave Macmillan.
- Porter, M. (2000) 'Location, competition, and economic development: Local clusters in a global economy', *Economic development quarterly*, Vol. 14, No. 1, pp.15-34.
- Portes, A. (2000) 'The two meanings of social capital', *Sociological forum*, Vol. 15, No. 1, pp.1-12.
- Powell, W. Koput, K. Bowie, J. Smith-Doerr, L. (2002) 'The spatial clustering of science and capital: Accounting for biotech firm-venture capital relationships', *Regional studies*, Vol. 36, No.3, pp.291-305.
- Prevezer, M. (1997) 'The dynamics of industrial clustering in biotechnology', *Small Business Economics*, Vol. 9, pp.255-271.

- Pollack, A. (2006) 'U.S. Finance Pulls Biotech Overseas', *The New York Times*, 12th July, [Online]
http://www.nytimes.com/2006/07/12/business/worldbusiness/12place.html?_r=1&pagewanted=print&oref=slogin (Accessed 12 February 2007)
- Regional Trends Publication Series 18-38, Office of National Statistics [online] Available from <http://www.statistics.gov.uk> Accessed Feb 2006 – April 2006
- Rickne, A. (2004) 'Prefirm Activities within the Life Sciences Sector', *Environment and planning C: Government and policy*, Vol. 22, pp.249-269.
- Robson, M.T. (1998) 'Self-employment in the UK regions', *Applied Economics*, Vol. 30, pp.313-322.
- Rosa, P. (1998) 'Entrepreneurial processes of businesses cluster formation and growth by 'habitual' entrepreneurs', *Entrepreneurship theory and practice*, Vol. 22, pp.43-63.
- Rosa, P. and Scott, M. (1999) 'Entrepreneurial diversification, business-cluster formation and growth', *Environment and planning C: Government and policy*, Vol. 17, pp.527-547.
- Rosiello, A. (2005) 'Comparing biotechnology innovation systems: The cases of Scotland, Sweden and Denmark', Innogen Working Paper No.25, September 2005. Available from: <http://www.genomicsnetwork.ac.uk/media/innogen%20working%20paper%2035.pdf> (Accessed 1 June 2008)
- Rosiello, A. and Orsenigo, L. (2008) 'A critical assessment of regional innovation policy in pharmaceutical biotechnology', IKD Working Paper No.27, February 2008. Available at: <http://www.open.ac.uk/ikd/workingpapers.shtml> (Accessed 1 June 2008)
- Rosiello, A. and Parris, S. (2008) 'Venture capital as a new form of intermediation: Discussing investment patterns in the UK bio-healthcare sector', Unpublished Manuscript.
- Rosenstein, J. (1988) 'The board and strategy: Venture capital and high technology', *Journal of business venturing*, Vol. 3, pp.159-170.
- Rosenstein, J., Bruno, A.V., Bygrave, W.D. and Taylor, N.T. (1993) 'The CEO venture capitalists and the board', *Journal of business venturing*, Vol. 8, pp.99-113.
- Rutterford, J. (2007) 'Private equity – Who's paying for their profits?', *Open2.net*, May 2008, Available from: http://www.open2.net/blogs/money/index.php/money/2007/06/05/private_equity (Accessed 12 January 2008)
- Sah, R.K. and Stiglitz, J.E. (1986) 'The architecture of economic systems: Hierarchies and polyarchies', *American economic review*, Vol. 76, No. 4, pp.716-729.
- Sahlman, W.A (1990) 'The structure and governance of venture-capital organizations', *Journal of financial economics*, Vol. 27, No. 2, pp.473-521.
- Sainsbury, D (1999) *Biotechnology clusters: Report of a team led by Lord Sainsbury, Minister for Science*, Department for Trade and Industry, London

- Sapienza, H.J. and Gupta, A.K. (1994) 'Impact of agency risks and task uncertainty on venture capitalist-CEO interaction', *The academy of management journal*, Vol. 37, No. 6, pp. 1618-1632.
- Sapsford, R. (1999) *Survey Research*, London, Sage Publications.
- Saxenian, A.L. (1991) 'The origins and dynamics of production networks in Silicon Valley', in Swedberg, R. (2000) (ed.) *Entrepreneurship: The social science view*, Oxford, Oxford University Press.
- Saxenian, A.L. (1996) *Regional advantage: Culture and competition in Silicon Valley and Route 128*, London, Harvard University Press.
- Scott, J (2000), *Social network analysis: A handbook*, London, Sage.
- Schumpeter, J.A. (1961) *The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle*, New York, Oxford University Press. Fifth Printing (1967).
- Schutjens, V. Stam, E. (2001) 'The evolution and nature of young firm networks: A longitudinal perspective', *Small business economics*, Vol. 21, pp.115-134.
- Searle, S., Graves, B. and Towler, C. (2003) 'Commercializing biotechnology in the UK', *Nature Bio entrepreneur*, [online]
http://www.nature.com/bioent/building/tech/012003/pf/bioent710_pf.html (Accessed 12 March 2008).
- Shepherd, J. (2006) 'Wealthy sultans of spin-off cash in on their ideas', *The Times Higher*, News, 20th January, p.8-9.
- Schurr, S. and Boone, J. (2006) 'Hedge fund signs Oxford spin-out deal', *The Financial Times*, 29th June, [Online] <http://www.ft.com/cms/s/0/4995337c-070b-11db-81d7-0000779e2340.html> (Accessed 24 July 2006)
- Sorenson, O. (2003) 'Social networks and industrial geography', *Journal of evolutionary economics*, Vol. 13, pp.513-527.
- Sorenson, O. and Stuart, T.E. (2001) 'Syndication networks and the spatial distribution of venture capital investments', *American journal of sociology*, Vol. 106, No .6, pp.1546-1588.
- Stock, J.H. and Watson, M.W. (2003) *Introduction to econometrics*, Boston, Pearson Education.
- Storper, M. (1993) 'Regional worlds of production: learning and innovation in the technology districts of France, Italy and the USA', *Regional studies*, Vol. 27, No. 5, pp.433-455.
- Stuart, T.E. and Ding, W.W. (2006) 'When do scientists become entrepreneurs? The social structural antecedents of commercial activity in the academic life sciences', *American journal of sociology*, Vol.112, No.1, pp.97-144.

- Stuart, T.E. and Sorenson, O. (2003) 'The geography of opportunity: spatial heterogeneity in founding rates and the performance of biotechnology firms', *Research policy*, Vol. 32, pp.229-253.
- Sunley, P., Klagge, B., Berndt, C. and Martin, R. (2005) 'Venture capital programmes in the UK and Germany: In what sense regional policies?' *Regional studies*, Vol. 39, No. 2, pp.255-273.
- Swann, P. and Prevezer, M. (1996) 'A comparison of the dynamics of industrial clustering in computing and biotechnology', *Research policy*, Vol. 25, pp.1139-1157.
- Tyler, R. (2006) 'Monday view: Show some enterprise and help entrepreneurs', *The Daily Telegraph*, 13th November, p.4.
- Useem, M (1984) *The inner circle: Large corporations and the rise of business*, Oxford, Oxford University Press.
- Von Burg, U. and Kenney, M. (2000) 'Venture capital and the birth of the local area networking industry', *Research policy*, Vol. 29, p.1135-1155.
- Walsh, V., Niosi, J. and Mustar, P. (1995) 'Small-firm formation in biotechnology: a comparison of France, Britain and Canada', *Technovation*, Vol.15, No.5, p.303-327.
- Wasserman, S. Faust, K. (1994) *Social network analysis: Methods and applications*, Cambridge, Cambridge University Press.
- Watts, D. W. (2003) *Six degrees. The science of a connected age*, London, Random House.
- Watts, D.W. (1999) 'Networks, dynamics, and the small-world phenomenon', *American journal of sociology*, Vol. 105, No. 2, pp.493-527.
- Warf, B (1995) 'Telecommunications and the changing geographies of knowledge transmission in the late 20th Century', in Bryson, J., Henry, N., Keeble, D. and Martin, R. (1999) (eds.) *The Economic Geography Reader*, (pp.57-63), Chichester, UK, John Wiley and Sons.
- Welch, I. (1992) 'Sequential sales, learning, and cascades', *Journal of finance*, Vol. 47, No.2, pp.695-732.
- Wilson, R. (1968) 'The theory of syndicates', *Econometrica*, Vol.36, No.1. pp.119-132.
- Willman, J. (2008) 'Making capital out of strengths', *The Financial Times*, 12th March. [online] <http://www.ft.com/cms/s/0/7c3bee1c-efd8-11dc-8a17-0000779fd2ac.html>, (Accessed 12 June 2008)
- Witt, P. (2004) 'Entrepreneurs' networks and the success of start-ups', *Entrepreneurship & Regional Development*, Vol.16, No.5, pp.391- 412.
- Wooldridge, J.M. (2002) *Econometric analysis of cross section and panel data*, London, The MIT Press.

Wooldridge, J.M. (2003) *Introductory econometrics: A Modern Approach, 2e*, Mason, Ohio, Thomson South Western.

Wright, M, Lockett, A (2003) 'The structure and management of alliances: Syndication in the venture capital industry', *Journal of management studies*, Vol. 40, No. 8, pp.2073-2102.

Wright, M., Robbie, K. and Ennew, C. (1997) 'Venture capitalists and serial entrepreneurs', *Journal of business venturing*, Vol.12, pp.227-249.

Yorkshire Forward (no date) Cluster Strategy. [Online] Available from: http://www.yorkshireforward.com/www/view.asp?content_id=113&parent_id=37, (Accessed 25 May 2008)

Zacharakis, A.L. and Meyer, G.D. (2000) 'The potential of actuarial decision models: can they improve the venture capital investment decision?' *Journal of businesses venturing*, Vol.15, pp.323-346.

Zajac, E.J. (1988) 'Interlocking directorates as an interorganizational strategy: A test of critical assumptions', *The academy of management journal*, Vol. 31, No. 2, pp.428-438.

Zook, M. (2002) 'Grounded capital; venture capital financing and the geography of the internet industry', *Journal of economic geography*, Vol.2, pp.151-177.

Zook, M (2004) 'The knowledge brokers: Venture capitalists, tacit knowledge and regional development', Vol.28, No.3, pp.621-641.

Zucker, L.G., Darby, M.R. and Brewer, M.B. (1998) 'Intellectual human capital and the birth of U.S. biotechnology enterprises', *The American economic review*, Vol. 88, No.1, pp.290-306.

12 Appendices

12.1 Appendix for Chapter 5

Table 13.1 Unrestricted co-efficient model

Unrestricted $\hat{\alpha}_i$	VC(amount)		VC(count)	
Variable	$\hat{\alpha}$	t-stat	$\hat{\alpha}$	t-stat
C	0.11	6.67 *	0.1	8.97 *
Yorkshire-ENT	1.78	0.29	-3.98	-0.57
E.Midlands-ENT	21.09	4.73 *	7.21	1.69
S.West-ENT	-3.97	-0.75	-2.07	-1.49
W.Midlands-ENT	-5.55	-0.63	3.08	0.71
Wales-ENT	-3.13	-1.17	4.78	0.91
N.Ireland-ENT	-2.41	-0.86	-2.91	-1.04
South-ENT	10.02	0.43	-5.29	-0.35
North-ENT	-3.62	-0.25	17.11	1.47
Yorkshire-FS	0.97	2.44 *	0.24	0.51
E.Midlands-FS	1.4	3.15 *	0.36	1.12
S.West-FS	-0.21	-0.61	-0.19	-1.57
W.Midlands-FS	-0.12	-0.26	0.21	1.19
Wales-FS	-0.26	-0.94	0.08	0.23
N.Ireland-FS	-0.44	-3.21 *	-0.04	-0.16
South-FS	-2.84	-4.92 *	-2.01	-4.28 *
North-FS	-0.3	-0.2	0.19	0.29
Yorkshire-DEG	-0.71	-1.46	0.15	0.25
E.Midlands-DEG	1.27	2.52 *	-0.04	-0.09
S.West-DEG	0.15	0.23	0.08	0.56
W.Midlands-DEG	1.03	2.02 *	0.12	0.42
Wales-DEG	-0.19	-1.14	0.03	0.1
N.Ireland-DEG	0.33	2.83 *	0.37	2.46 *
South-DEG	0.34	0.58	0.6	0.5
North-DEG	1.01	0.77	0.96	1.28
Yorkshire-PAT	-1.03	-3.77 *	-0.77	-1.97
E.Midlands-PAT	-4.64	-5.71 *	-0.7	-1.05
S.West-PAT	-1.11	-1.04	-0.63	-3.28 *
W.Midlands-PAT	-0.67	-0.68	-0.7	-2.27 *
Wales-PAT	1.32	0.75	-2.16	-1.33
N.Ireland-PAT	0.12	0.53	-0.37	-0.84
South-PAT	2.71	3.64 *	2.02	3.19 *
North-PAT	1.75	0.31	0.27	0.11
Fixed Effects (Cross)				
Yorkshire-C	-0.09		-0.04	
E.Midlands-C	-0.35		-0.11	
S.West-C	0.01		0.01	
W.Midlands-C	-0.06		-0.06	
Wales-C	-0.03		-0.09	
N.Ireland-C	-0.09		-0.09	
South-C	0.69		0.59	
North-C	-0.08		-0.2	
Adjusted R-squared	0.95		0.97	
S.E. of regression	0.04		0.03	
Sum squared resid	0.17		0.08	
Log likelihood	322.94		380.99	
Durbin-Watson stat	1.85		0.94	
Mean dependent var	0.12		0.11	
S.D. dependent var	0.17		0.14	
Akaike Info criterion	-3.54		-4.26	
Schwarz criterion	-2.77		-3.49	
F-statistic	84.45		116.52	
Prob(F-statistic)	***		***	

12.2 Appendix for Chapter 6

Table 13. 2 Least squares results based on VC count series

Least squares	Bio/pharma			Rest			All deals		
Variable	β	Std. Error	Sig	Coefficient	Std. Error	Sig	Coefficient	Std. Error	Sig
Const	-0.13	0.54		0.22	0.22		0.59	0.31	*
Ent	-29.00	11.09	**	-5.40	5.31		-9.55	5.24	*
FS	11.12	3.18	***	8.71	1.42	***	9.38	1.20	***
Deg	-13.86	2.75	***	0.26	1.60		-2.12	1.13	*
R&D	5.31	0.21	***	2.51	0.28	***	3.11	0.28	***
R&D ratio	2.53	0.19	***	1.28	0.13	***	1.54	0.11	***
VC_public	1.54	0.36	***	-0.82	1.15		-1.16	0.74	
Endogeneity	*			N/S			N/S		
Adjusted R-squared	0.73			0.73			0.76		
S.E. of regression	0.53			0.46			0.44		
SSR	11.57			8.81			7.79		
Logl'hood	-33.96			-27.43			-24.48		
DW	1.80			0.78			0.96		
Akaike info criterion	1.71			1.43			1.31		
Schwarz criterion	1.98			1.71			1.58		
F-statistic	22.69			21.98			26.38		

Table 13.3 Least squares results based on VC value series

Least squares	Bio/pharma			Rest			All deals		
Variable	β	Std. Error	Sig	Coefficient	Std. Error	Sig	Coefficient	Std. Error	Sig
Const	-0.51	3.07		4.41	1.51	***	3.98	1.54	**
Ent	-99.10	47.20	**	16.36	16.78		16.15	18.39	
FS	45.84	18.81	**	14.20	7.79	*	14.27	7.82	*
Deg	-52.04	20.02	**	-2.60	8.89		-7.67	9.29	
R&D	17.96	2.34	***	3.15	1.44	**	4.63	1.40	***
R&D ratio	10.37	1.90	***	1.51	1.03		2.46	0.99	**
VC_public	4.47	2.55	*	-9.30	7.49		-1.20	5.90	
Endogeneity	N/S			N/S			N/S		
Adjusted R-squared	0.48			0.61			0.59		
S.E. of regression	2.92			1.07			1.12		
SSR	350.17			46.66			51.32		
Logl'hood	-115.80			-67.43			-69.71		
DW	1.60			1.42			1.05		
Akaike info criterion	5.12			3.10			3.20		
Schwarz criterion	5.39			3.37			3.47		
F-statistic	8.24			13.23			12.16		

Table 13.4 Dummy variables from fixed effects regressions

Region	Biopharma*		Rest of sectors		All deals	
	Deal count	Deal value	Deal count	Deal value	Deal count	Deal value
East	0.9	5	0.66	4.95	0.65	4.83
S.East	0.29	4.95	0.84	3.64	0.48	3.58
Scotland	0.42	1.78	1.03	0.94	0.95	0.98
London	-0.25	5.53	0.82	0.67	0.13	0.87
S.West	-0.29	-0.42	-0.2	0.85	-0.17	0.87
N.East	0.62	1.5	0.14	-0.51	0.31	-0.41
W.Midlands	-0.56	-3.75	-0.14	-0.66	-0.09	-0.57
N.West	-0.74	-2.5	-1.61	-0.59	-1.42	-0.88
E.Midlands	-0.14	-1.2	-0.86	-1.61	-0.68	-1.67
Yorkshire	0.23	-0.41	-0.48	-1.91	-0.35	-1.89
Wales	0.29	-6.07	-0.06	-2.33	0.01	-2.4
N.Ireland	-0.19	-4.4	-0.13	-3.44	0.19	-3.3

* Biopharma coefficients for fixed effects were not shown to be jointly significant in regressions

12.3 Appendix for Chapter 8

Figure 13.1 Histogram of dependent variable – number of investors per firm

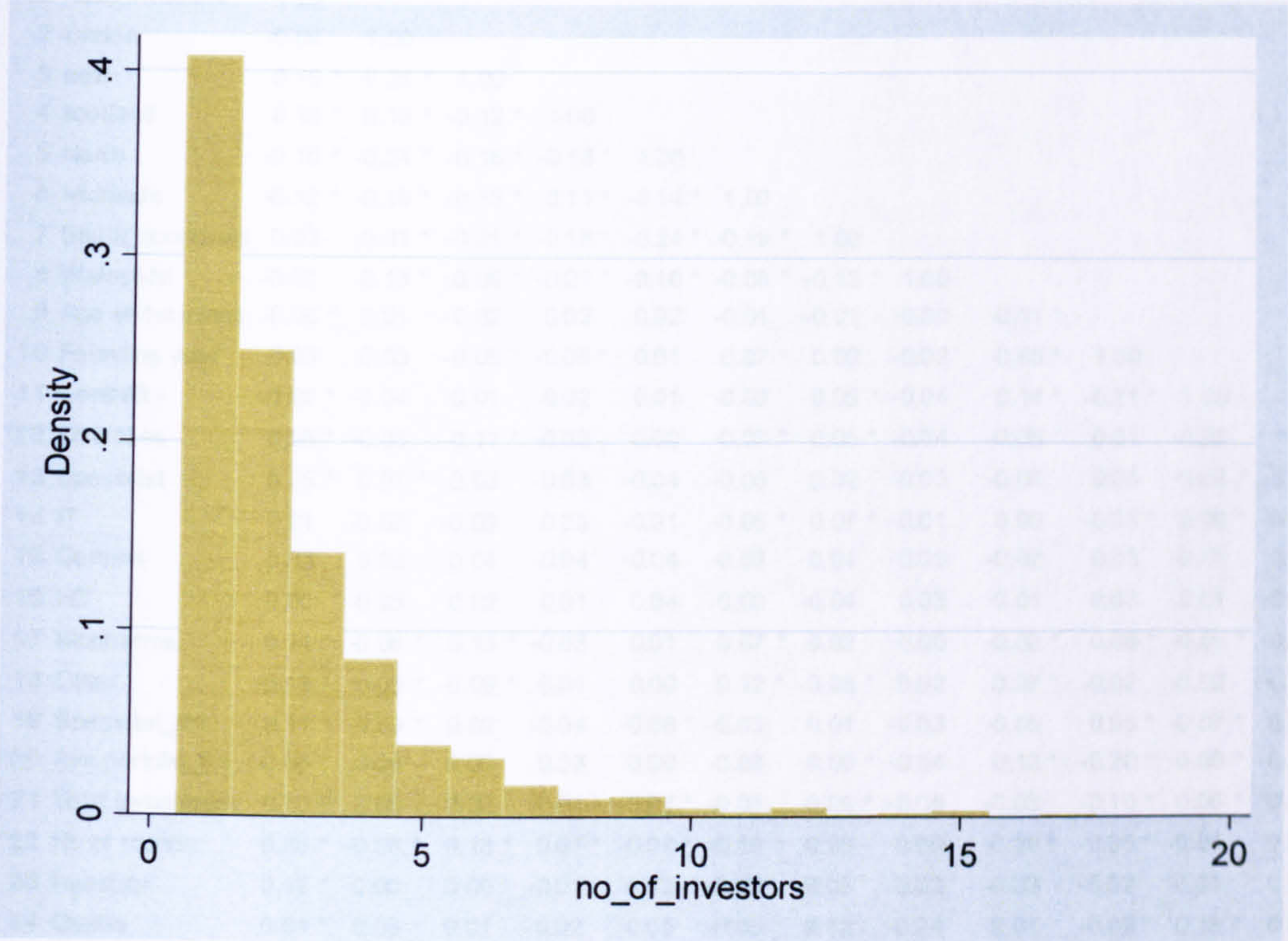


Table 13.5 Pairwise correlation coefficients of variables (* indicates significant at 5%)

No. Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1 no of investors	1.00												
2 lndon	-0.04	1.00											
3 east	0.15 *	-0.21 *	1.00										
4 scotland	0.10 *	-0.18 *	-0.12 *	1.00									
5 North	-0.10 *	-0.24 *	-0.16 *	-0.13 *	1.00								
6 Midlands	-0.12 *	-0.19 *	-0.13 *	-0.11 *	-0.14 *	1.00							
7 South_combined	0.03	-0.31 *	-0.21 *	-0.18 *	-0.24 *	-0.19 *	1.00						
8 Wales&NI	-0.01	-0.13 *	-0.09 *	-0.07 *	-0.10 *	-0.08 *	-0.13 *	1.00					
9 Age at 1st invest	-0.08 *	0.01	-0.02	0.02	0.02	-0.01	-0.01	0.00	-0.11 *				
10 Founding year	-0.03	0.03	-0.05 *	-0.06 *	0.01	0.07 *	0.00	-0.02	-0.68 *	1.00			
11 Centrality	-0.08 *	-0.04	0.01	0.02	0.01	-0.03	0.05 *	-0.04	0.14 *	-0.21 *	1.00		
12 Overseas	0.35 *	-0.05	0.11 *	-0.03	0.00	-0.07 *	0.05 *	-0.04	-0.05	0.01	-0.02	1.00	
13 Specialist	0.25 *	0.07 *	0.03	-0.03	-0.04	-0.05	0.02	-0.03	-0.06	0.05	-0.08 *	0.12 *	1.00
14 IT	0.01	-0.02	-0.03	0.03	-0.01	-0.05 *	0.07 *	-0.01	0.00	-0.05 *	0.06 *	-0.04	-0.01
15 Comms	0.03	0.03	0.04	-0.04	-0.04	-0.03	0.04	-0.03	-0.02	0.03	-0.01	-0.01	-0.06 *
16 HC	0.00	-0.03	0.02	0.01	0.04	0.00	-0.04	0.03	-0.01	0.03	0.01	-0.02	-0.08 *
17 Biopharma	0.24 *	-0.06 *	0.13 *	-0.03	0.01	-0.07 *	0.02	0.00	-0.08 *	0.06 *	-0.05 *	0.24 *	0.20 *
18 Other	-0.19 *	0.05 *	-0.09 *	0.01	0.00	0.12 *	-0.08 *	0.02	0.07 *	-0.02	-0.02	-0.09 *	-0.04
19 Specialist_R1	0.11 *	0.09 *	0.02	-0.04	-0.06 *	-0.03	0.01	-0.03	-0.05	0.05 *	-0.07 *	0.05 *	0.78 *
20 Ave portfolio_R1	-0.06 *	-0.04	0.00	0.03	0.00	-0.03	0.06 *	-0.04	0.10 *	-0.20 *	0.90 *	-0.02	-0.07 *
21 Total investment	0.35 *	0.05	0.02	-0.01	-0.07 *	-0.05	0.06 *	-0.05	-0.03	-0.10 *	0.06 *	0.16 *	0.12 *
22 No of rounds	0.66 *	-0.06 *	0.18 *	0.07 *	-0.07 *	-0.10 *	0.03	0.00	-0.26 *	-0.05 *	-0.04	0.20 *	0.13 *
23 investsq	0.15 *	0.00	0.00	-0.01	-0.03	-0.02	0.05	-0.02	-0.03	-0.02	-0.01	0.03	0.10 *
24 Quality	0.04 *	0.03	0.01	-0.02	0.00	-0.05	0.02	-0.04	0.01	-0.09 *	0.12 *	-0.01	-0.02
25 P_local	0.13 *	-0.03	-0.08 *	0.16 *	0.13 *	-0.03	-0.22 *	0.22 *	-0.07 *	0.10 *	-0.26 *	-0.06 *	0.05 *
26 P_national	-0.19 *	-0.05	0.01	-0.07 *	-0.05 *	0.11 *	0.13 *	-0.15 *	0.08 *	-0.09 *	0.34 *	-0.11 *	-0.14 *

	14	15	16	17	18	19	20	21	22	23	24	25	26
14 IT	1.00												
15 Comms	-0.24 *	1.00											
16 HC	-0.21 *	-0.10 *	1.00										
17 Biopharma	-0.25 *	-0.12 *	-0.10 *	1.00									
18 Other	-0.55 *	-0.26 *	-0.23 *	-0.28 *	1.00								
19 Specialist_R1	0.00	-0.05 *	-0.06 *	0.10 *	0.00	1.00							
20 Ave portfolio_R1	0.07 *	-0.01	0.00	-0.06 *	-0.03	-0.06 *	1.00						
21 Total investment	-0.02	-0.01	-0.06 *	0.05	0.02	0.11 *	0.12 *	1.00					
22 No of rounds	0.03	0.06 *	0.02	0.19 *	-0.20 *	-0.01	-0.02	0.25 *	1.00				
23 investsq	-0.02	-0.02	-0.03	0.00	0.05	0.13 *	0.02	0.81 *	0.16 *	1.00			
24 Quality	0.07 *	-0.06	-0.03	-0.03	0.01	-0.04	0.08	0.04	-0.06	0.00	1.00		
25 P_local	0.00	0.01	-0.01	0.00	0.00	0.05 *	-0.24 *	0.00	0.04	0.01	-0.07 *	1.00	
26 P_national	-0.01	-0.02	0.02	-0.04	0.04	-0.13 *	0.29 *	-0.09 *	-0.06 *	-0.06 *	0.04	-0.74 *	1.00

Table 13.6 Poisson Regression model

Model	1	2	3	4a	4b	4c	5	6
london	0.39704 (0.11086) ***		0.21835 (0.12307) *	0.19845 (0.12394)	0.17978 (0.12321)	0.20497 (0.12353) .	0.17425 (0.11886)	0.17600 (0.12492)
east	0.70006 (0.11924) ***		0.26456 (0.13462) **	0.32612 (0.12720) ***	0.31410 (0.12615) **	0.29992 (0.12849) **	0.29827 (0.12246) **	0.27050 (0.13112) ..
scotland	0.77886 (0.12093) ***		0.54566 (0.13119) ***	0.48961 (0.12939) ***	0.46773 (0.12756) ***	0.46940 (0.13296) ***	0.48080 (0.12711) ***	0.46150 (0.13397) ***
North	0.12058 (0.11864)		0.10636 (0.12778)	0.01425 (0.12769)	-0.01791 (0.12764)	0.01573 (0.12912)	0.00354 (0.12897)	0.00324 (0.13038)
South	0.48976 (0.11011) ***		0.33443 (0.11569) ***	0.38054 (0.11546) ***	0.37470 (0.11392) ***	0.38982 (0.11534) ***	0.35429 (0.11573) ***	0.35900 (0.11834) ***
Wales&NI	0.39428 (0.15123) ***		0.32143 (0.14101) **	0.17070 (0.13889)	0.15238 (0.13749)	0.14717 (0.13969)	0.14051 (0.16480)	0.11412 (0.14127)
IT	0.31330 (0.06993) ***		0.21327 (0.07983) ***	0.19683 (0.07257) ***	0.18979 (0.07277) ***	0.20750 (0.07301) ***	0.18813 (0.06653) ***	0.19606 (0.07366) ***
Comms	0.37635 (0.09419) ***		0.21631 (0.10297) **	0.14049 (0.10561)	0.12424 (0.10907)	0.14229 (0.10821)	0.12872 (0.09448)	0.12814 (0.10758)
HC	0.30216 (0.09814) ***		0.25765 (0.10328) **	0.25643 (0.09629) ***	0.25680 (0.09588) ***	0.24261 (0.09716) **	0.25544 (0.09825) ***	0.24176 (0.09811) ..
Bio	0.80215 (0.08470) ***		0.46060 (0.09353) ***	0.27459 (0.09061) ***	0.27129 (0.09126) ***	0.31435 (0.09238) ***	0.28460 (0.07787) ***	0.32190 (0.09246) ***
Age at first invest	-0.03327 (0.00888) ***		-0.00091 (0.01136)	-0.00219 (0.01090)	-0.00113 (0.01093)	-0.00305 (0.01118)	-0.00071 (0.00960)	-0.00132 (0.01113)
Founding	-0.01177 (0.00405) ***		0.00597 (0.00929)	-0.00384 (0.00938)	-0.00258 (0.00934)	-0.00292 (0.00966)	-0.00346 (0.00683)	-0.00254 (0.00947)
No. of rounds	0.34771 (0.02008) ***	0.31678 (0.01885) ***	0.30014 (0.01913) ***	0.30058 (0.01914) ***	0.30635 (0.01859) ***	0.30415 (0.01601) ***	0.31057 (0.01840) ***	
Total invest	0.01950 (0.00341) ***	0.01870 (0.00269) ***	0.01490 (0.00247) ***	0.01470 (0.00244) ***	0.01530 (0.00259) ***	0.01440 (0.00179) ***	0.01470 (0.00259) ***	
Investsqr	-0.00008 (0.00003) ***	-0.00007 (0.00002) ***	-0.00006 (0.00001) ***	-0.00006 (0.00001) ***	-0.00006 (0.00001) ***	-0.00006 (0.00001) ***	-0.00006 (0.00001) ***	
Quality	0.22160 (0.09800) **	0.20018 (0.09575) **	0.20838 (0.08812) **	0.20137 (0.09080) **	0.24353 (0.08962) ***	0.20975 (0.08739) **	0.24128 (0.08005) ***	
Overseas			0.45332 (0.08910) ***	0.46005 (0.08969) ***	0.47214 (0.08962) ***	0.40015 (0.08093) ***	0.40946 (0.09672) ***	
P_local			0.48391 (0.08626) ***	0.52984 (0.08447) ***	0.49791 (0.08702) ***	0.28726 (0.11314) **	0.27207 (0.12582) ..	
P_national						-0.26914 (0.11304) **	-0.30821 (0.11220) ***	
Centrality			-3.21335 (1.21678) ***		-3.47738 (1.20840) ***	-2.33995 (1.44532) ***	-2.45350 (1.24049) ..	
Ave. portfolio_R1					-0.00015 (0.00013)			

Model (continued)	1	2	3	4a	4b	4c	5	6
Specialist				0.35641 (0.08189) ***	0.36063 (0.08265) ***		0.33346 (0.07024) **	
Specialist_R1						0.27128 (0.11941) **		0.24755 (0.11886) **
Const.	23.63933 (8.09389) ***	-0.22103 (0.06067) ***	-12.54837 (18.59615)	6.97778 (18.77810)	4.43814 (18.68944)	5.13061 (19.33142)	6.44393 (13.67568)	4.61876 (18.92858)
Loglikelihood	-2707.31	-1480.05	-1442.18	-1385.84	-1375.24	-1392.18	-1381.07	-1388.4
Obs	1562	1013	1013	1013	1004	1013	1013	1013
LR model test	467.48 ***	880.44 ***	956.32 ***	1072.87 ***	1063.53 ***	1056.18 ***	1078.39 ***	1063.55 ***
Compared to model:	n/a	n/a	2	3	3	3	4a	4c
Testparm				18.58 ***	16.17 ***	99.96 ***	5.53 **	7.58 **
LR test			75.88 ***	116.55 ***	n/a	99.85 ***	5.67 **	7.37 ***
Maximum LM	n/a	124	134	129	129	127	126	124

12.4 Appendix for Chapter 10

Table 13.7 Description of investors, in terms of presence and office location relative to deal

Region	Investor presence in dataset			Office locations relative to deal				
	National	Multi-regional	Local region only	Local	Next region	within UK	Overseas	Uncoded
London	39%	20%	39%	44%	8%	6%	33%	10%
East	46%	17%	36%	14%	33%	3%	34%	16%
Scot	35%	11%	54%	26%	4%	30%	22%	18%
Yorks	62%	5%	29%	41%	0%	41%	5%	14%

Investor presence is coded removing investors overseas. These investors are coded as without a UK office.

The regional networks in this section have vertices are colour co-ordinated to represent the geographically coverage the UK of each investor. The colours are consistent with colours used throughout the chapter, with the addition of a new colour for representing the biopharmaceutical firms in the 2 mode representations. The numerical codes refer to the location of the investors relative to the company. 1 = in same region, 2 = bordering region, 3 = nationally, 4 = overseas, 5 = uncoded.

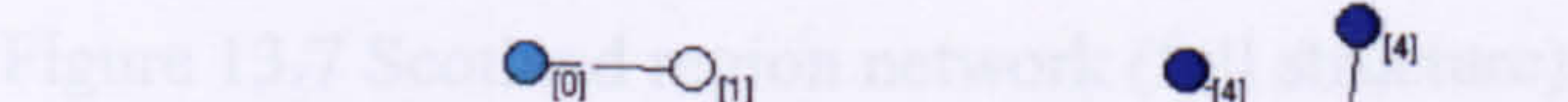
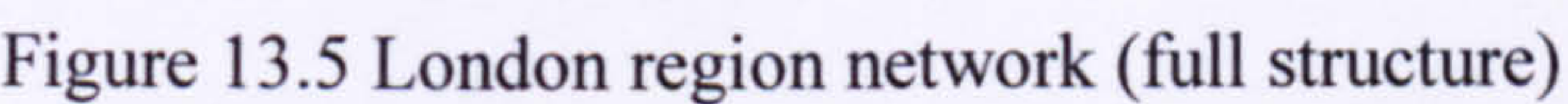


Figure 13.6 Scotland region network (only multiple affiliated investors showing)

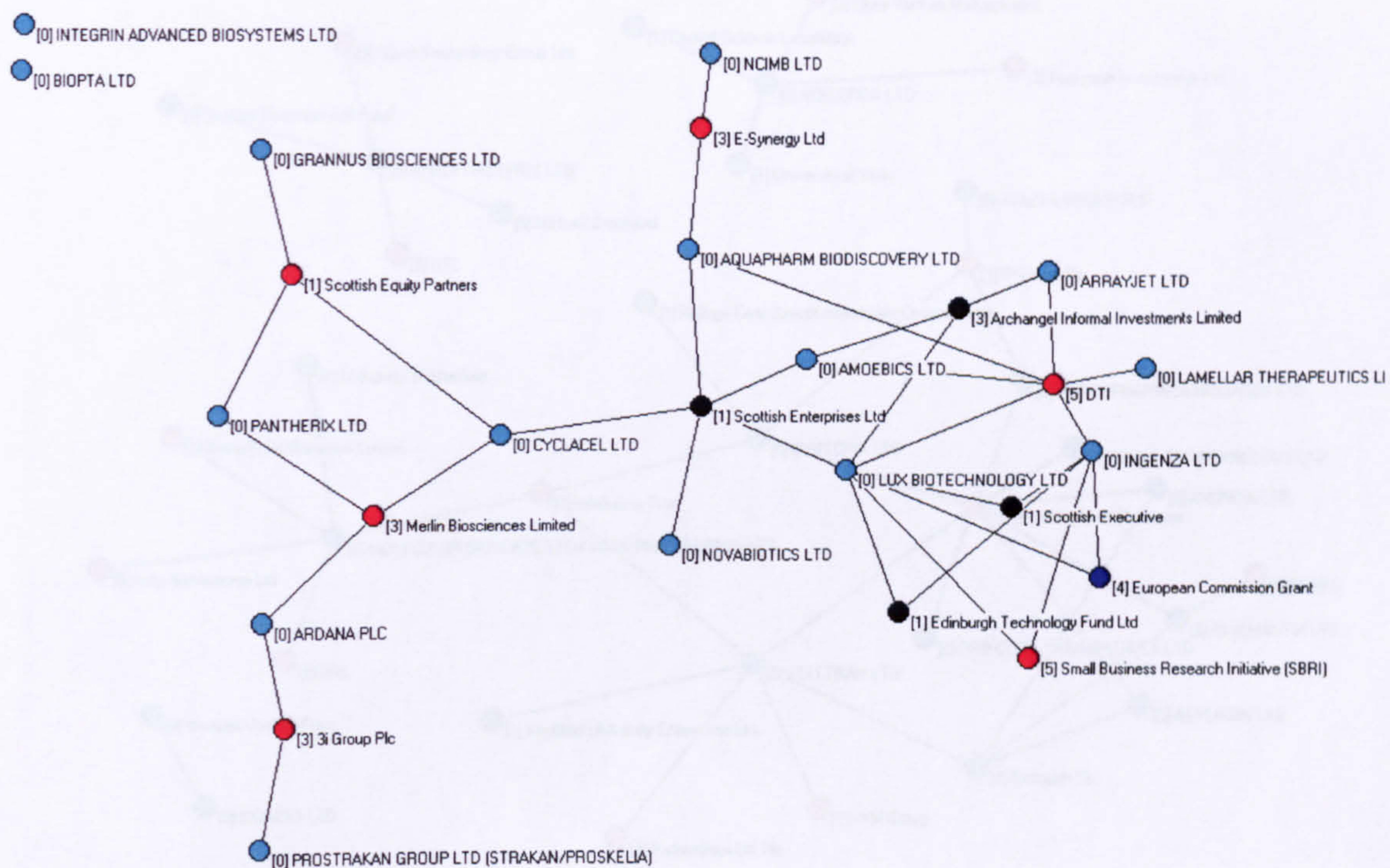


Figure 13.7 Scotland region network (full structure)

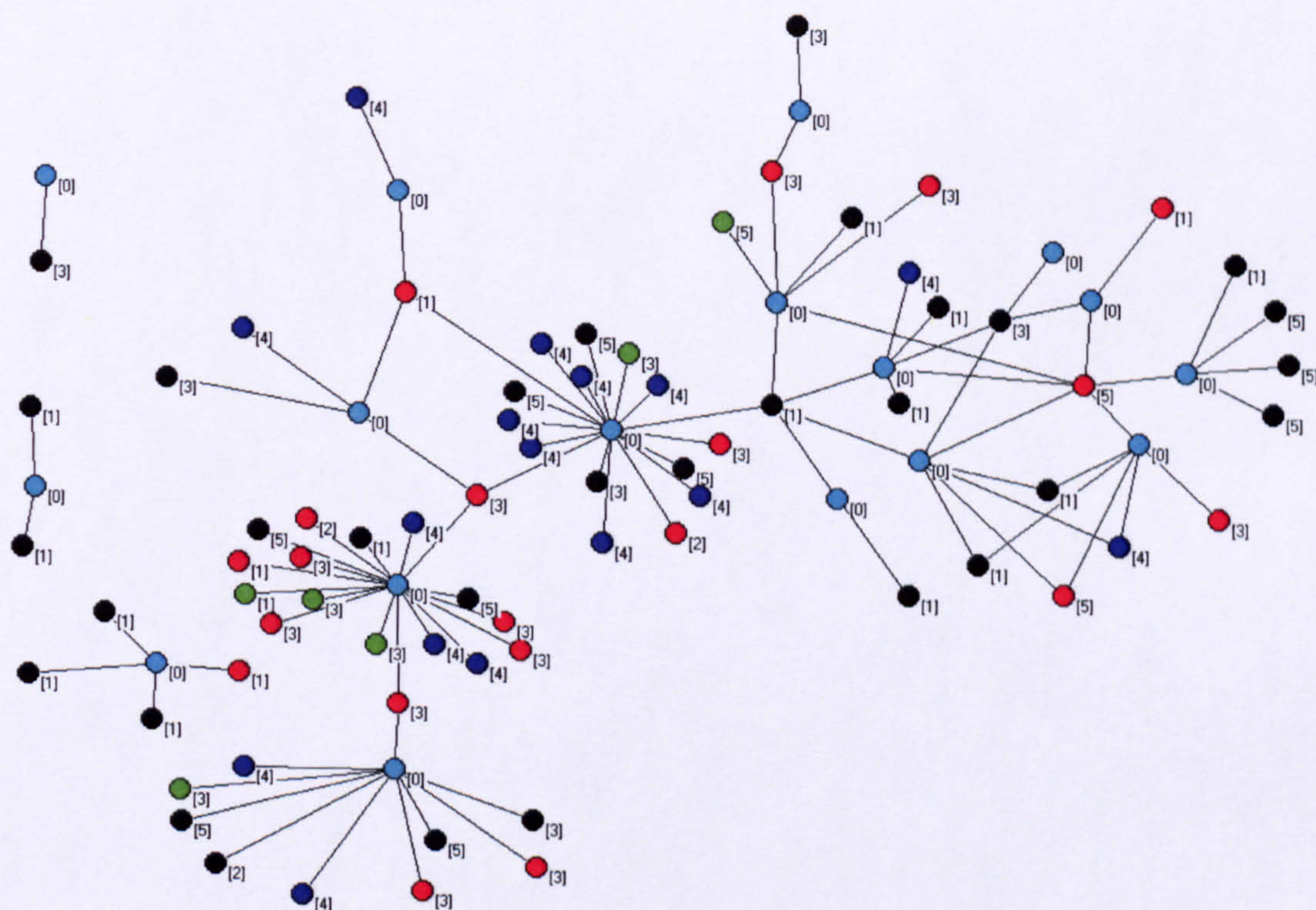


Figure 13.8 Yorkshire region network (full structure)

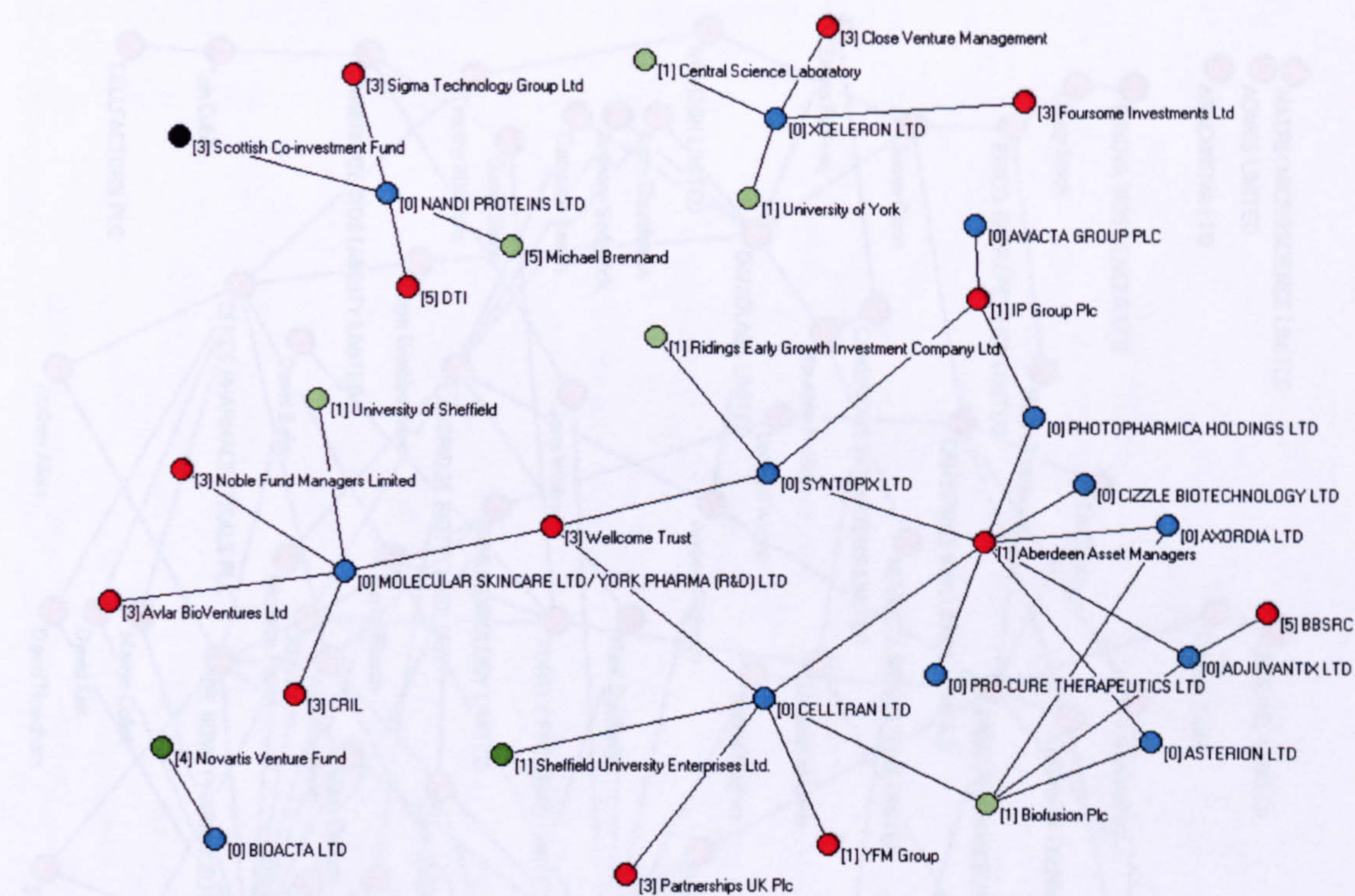


Figure 13.9 Eastern region director affiliation network

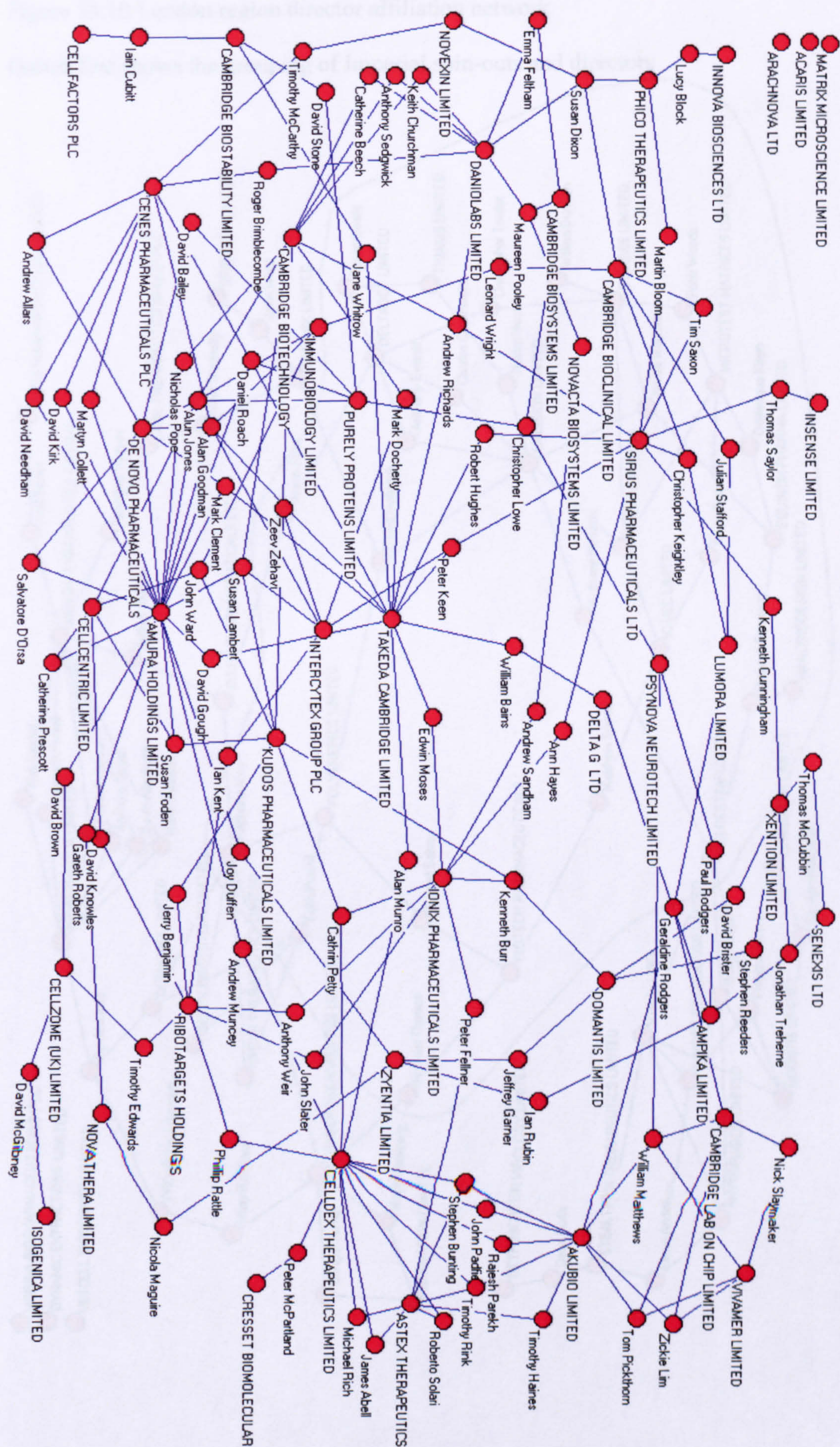


Figure 13.10 London region director affiliation network

Figure 13.11 Scotland director affiliation network

Dotted line shows the grouping of Imperial spin-outs and directors

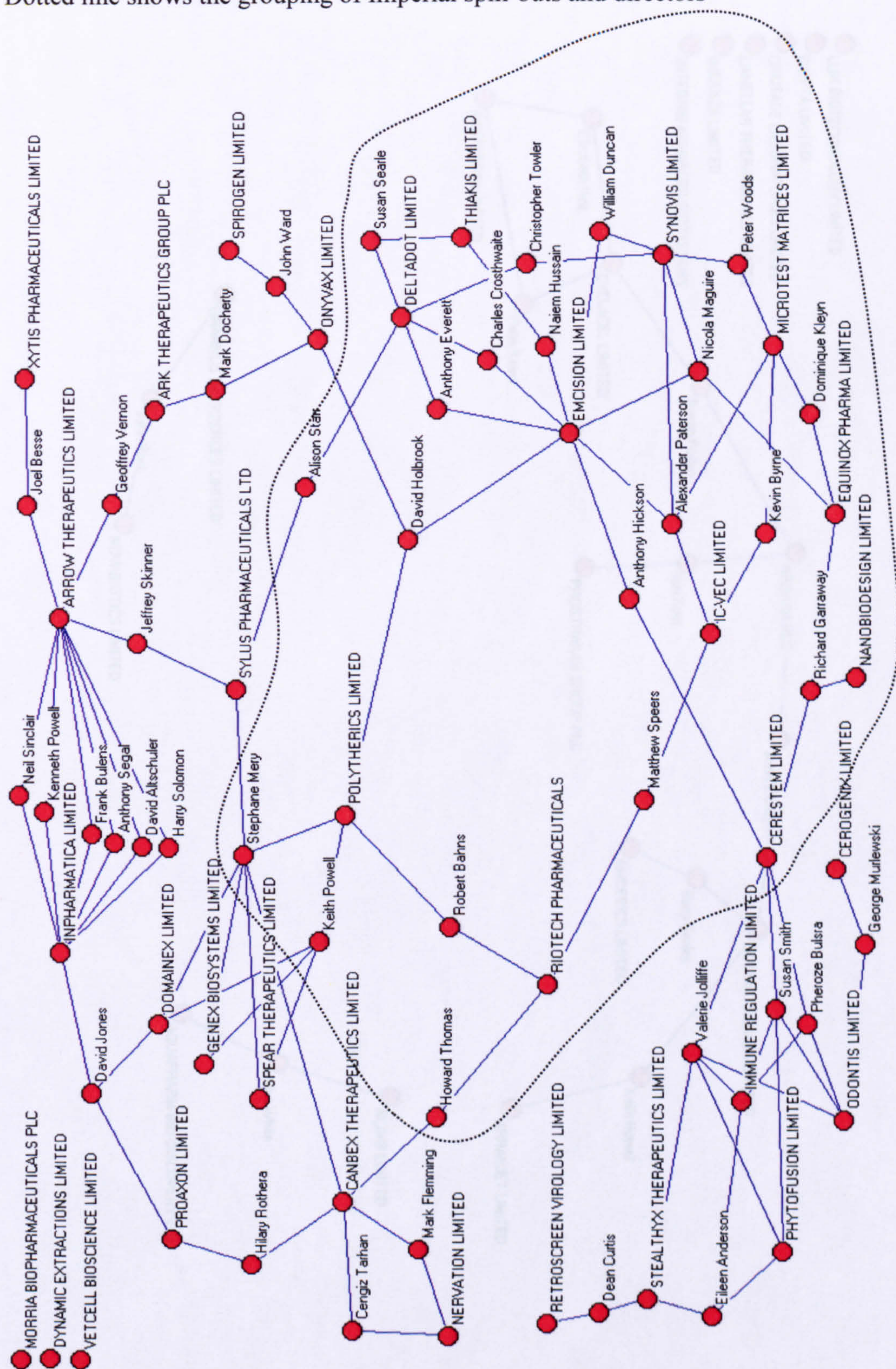


Figure 13.11 Scotland director affiliation network

Figure 13.12 Yorkshire director affiliation network

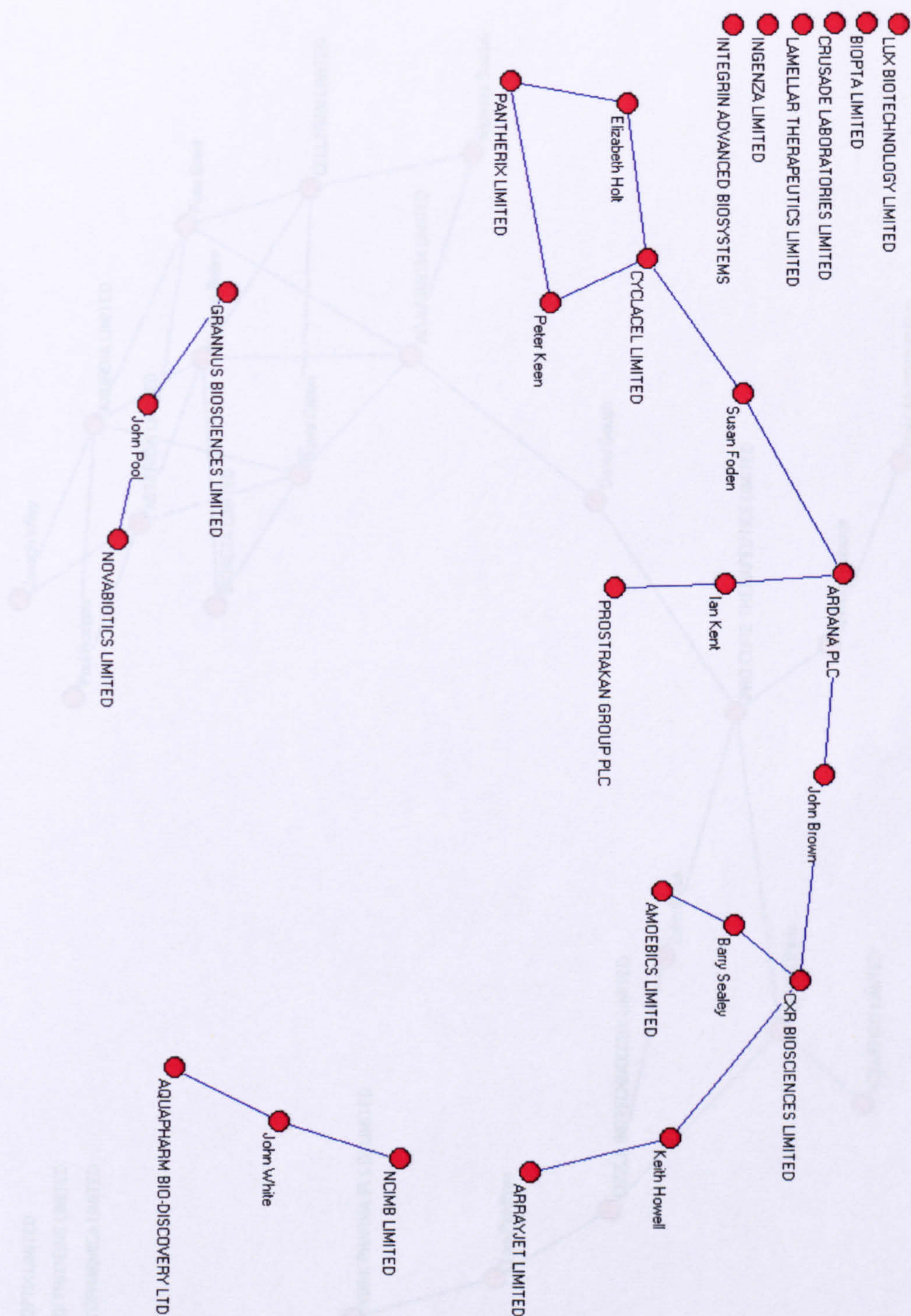


Figure 13.12 Yorkshire director affiliation network

